

Engineers, Life and Physical Scientists, and Related Occupations



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Occupations Included in this Reprint

Agricultural and food scientists
Architects, except landscape and naval
Atmospheric scientists
Biological and medical scientists
Chemists and materials scientists
Conservation scientists and foresters
Drafters
Engineering technicians
Engineers
 Aerospace engineers
 Agricultural engineers
 Biomedical engineers
 Chemical engineers
 Civil engineers
 Computer hardware engineers
 Electrical and electronics engineers, except computer
 Environmental engineers
 Industrial engineers, including health and safety
 Materials engineers
 Mechanical engineers
 Mining and geological engineers, including
 mining safety engineers
 Nuclear engineers
 Petroleum engineers
Environmental scientists and geoscientists
Landscape architects
Physicists and astronomers
Science technicians
Surveyors, cartographers, photogrammetrists, and
 surveying technicians

Agricultural and Food Scientists

(O*NET 19-1011.00, 19-1012.00, 19-1013.01, 19-1013.02)

Significant Points

- A large proportion, about 41 percent, of salaried agricultural and food scientists works for Federal, State, and local governments.
- A bachelor's degree in agricultural science is sufficient for some jobs in applied research; a master's or doctoral degree is required for basic research.

Nature of the Work

The work of agricultural and food scientists plays an important part in maintaining the Nation's food supply by ensuring agricultural productivity and the safety of the food supply. Agricultural scientists study farm crops and animals, and develop ways of improving their quantity and quality. They look for ways to improve crop yield with less labor, control pests and weeds more safely and effectively, and conserve soil and water. They research methods of converting raw agricultural commodities into attractive and healthy food products for consumers.

Agricultural science is closely related to biological science, and agricultural scientists use the principles of biology, chemistry, physics, mathematics, and other sciences to solve problems in agriculture. They often work with biological scientists on basic biological research and on applying to agriculture the advances in knowledge brought about by biotechnology.

Many agricultural scientists work in basic or applied research and development. Others manage or administer research and development programs, or manage marketing or production operations in companies that produce food products or agricultural chemicals, supplies, and machinery. Some agricultural scientists are consultants to business firms, private clients, or government.

Depending on the agricultural or food scientist's area of specialization, the nature of the work performed varies.

Food science. Food scientists and technologists usually work in the food processing industry, universities, or the Federal Government, and help meet consumer demand for food products that are healthful, safe, palatable, and convenient. To do this, they use their knowledge of chemistry, microbiology, and other sciences to develop new or better ways of preserving, processing, packaging, storing, and delivering foods. Some food scientists engage in basic research, discovering new food sources; analyzing food content to determine levels of vitamins, fat, sugar, or protein; or searching for substitutes for harmful or undesirable additives, such as nitrites. They also develop ways to process, preserve, package, or store food according to industry and government regulations. Others enforce government regulations, inspecting food processing areas and ensuring that sanitation, safety, quality, and waste management standards are met. Food technologists generally work in product development, applying the findings from food science research to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious, and wholesome food.

Plant science. Agronomy, crop science, entomology, and plant breeding are included in plant science. Scientists in these disciplines study plants and their growth in soils, helping producers of food, feed, and fiber crops to continue to feed a growing population while conserving natural resources and maintaining the environment. Agronomists and crop scientists not only help increase productivity, but also study ways to improve the nutritional value of crops and the quality of seed. Some crop scientists study the

breeding, physiology, and management of crops and use genetic engineering to develop crops resistant to pests and drought. Entomologists conduct research to develop new technologies to control or eliminate pests in infested areas and to prevent the spread of harmful pests to new areas, as well as technologies that are compatible with the environment. They also conduct research or engage in oversight activities aimed at halting the spread of insect-borne disease.

Soil science. Soil scientists study the chemical, physical, biological, and mineralogical composition of soils as they relate to plant or crop growth. They also study the responses of various soil types to fertilizers, tillage practices, and crop rotation. Many soil scientists who work for the Federal Government conduct soil surveys, classifying and mapping soils. They provide information and recommendations to farmers and other landowners regarding the best use of land, plant growth, and methods to avoid or correct problems such as erosion. They may also consult with engineers and other technical personnel working on construction projects about the effects of, and solutions to, soil problems. Because soil science is closely related to environmental science, persons trained in soil science also apply their knowledge to ensure environmental quality and effective land use.

Animal science. Animal scientists work to develop better, more efficient ways of producing and processing meat, poultry, eggs, and milk. Dairy scientists, poultry scientists, animal breeders, and other related scientists study the genetics, nutrition, reproduction, growth,



Many agricultural and food scientists conduct research in offices and laboratories.

and development of domestic farm animals. Some animal scientists inspect and grade livestock food products, purchase livestock, or work in technical sales or marketing. As extension agents or consultants, animal scientists advise agricultural producers on how to upgrade animal housing facilities properly, lower mortality rates, handle waste matter, or increase production of animal products, such as milk or eggs.

Working Conditions

Agricultural scientists involved in management or basic research tend to work regular hours in offices and laboratories. The work environment for those engaged in applied research or product development varies, depending on the discipline of agricultural science and on the type of employer. For example, food scientists in private industry may work in test kitchens while investigating new processing techniques. Animal scientists working for Federal, State, or university research stations may spend part of their time at dairies, farrowing houses, feedlots, or farm animal facilities or outdoors conducting research associated with livestock. Soil and crop scientists also spend time outdoors conducting research on farms and agricultural research stations. Entomologists work in laboratories, insectories, or agricultural research stations, and may also spend time outdoors studying or collecting insects in their natural habitat.

Employment

Agricultural and food scientists held about 17,000 jobs in 2000. In addition, several thousand persons held agricultural science faculty positions in colleges and universities. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

About 41 percent of all nonfaculty salaried agricultural and food scientists work for Federal, State, or local governments. Nearly 2 out of 3 worked for the Federal Government in 2000, mostly in the Department of Agriculture. In addition, large numbers worked for State governments at State agricultural colleges or agricultural research stations. Some worked for agricultural service companies; others worked for commercial research and development laboratories, seed companies, pharmaceutical companies, wholesale distributors, and food products companies. About 4,000 agricultural scientists were self-employed in 2000, mainly as consultants.

Training, Other Qualifications, and Advancement

Training requirements for agricultural scientists depend on their specialty and on the type of work they perform. A bachelor's degree in agricultural science is sufficient for some jobs in applied research or for assisting in basic research, but a master's or doctoral degree is required for basic research. A Ph.D. in agricultural science usually is needed for college teaching and for advancement to administrative research positions. Degrees in related sciences such as biology, chemistry, or physics or in related engineering specialties also may qualify persons for some agricultural science jobs.

All States have a land-grant college that offers agricultural science degrees. Many other colleges and universities also offer agricultural science degrees or some agricultural science courses. However, not every school offers all specialties. A typical undergraduate agricultural science curriculum includes communications, economics, business, and physical and life sciences courses, in addition to a wide variety of technical agricultural science courses. For prospective animal scientists, these technical agricultural science courses might include animal breeding, reproductive physiology, nutrition, and meats and muscle biology.

Students preparing as food scientists take courses such as food chemistry, food analysis, food microbiology, food engineering, and

food processing operations. Those preparing as crop or soil scientists take courses in plant pathology, soil chemistry, entomology, plant physiology, and biochemistry, among others. Advanced degree programs include classroom and fieldwork, laboratory research, and a thesis or dissertation based on independent research.

Agricultural and food scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Most of these scientists also need an understanding of basic business principles, and the ability to apply basic statistical techniques. Employers increasingly prefer job applicants who are able to apply computer skills to determine solutions to problems, to collect and analyze data, and for the control of processes.

The American Society of Agronomy offers certification programs in crops, agronomy, crop advising, soils, horticulture, plant pathology, and weed science. To become certified, applicants must pass designated examinations and meet certain standards with respect to education and professional work experience.

Agricultural scientists who have advanced degrees usually begin in research or teaching. With experience, they may advance to jobs such as supervisors of research programs or managers of other agriculture-related activities.

Job Outlook

Employment of agricultural scientists is expected to grow more slowly than the average for all occupations through 2010. Additionally, the need to replace agricultural and food scientists who retire or otherwise leave the occupation permanently will account for many more job openings than will projected growth, particularly in academia.

Past agricultural research has resulted in the development of higher yielding crops, crops with better resistance to pests and plant pathogens, and chemically based fertilizers and pesticides. Further research is necessary as insects and diseases continue to adapt to pesticides, and as soil fertility and water quality continue to need improvement. Agricultural scientists are using new avenues of research in biotechnology to develop plants and food crops that require less fertilizer, fewer pesticides and herbicides, and even less water for growth. Agricultural scientists will be needed to balance increased agricultural output with protection and preservation of soil, water, and ecosystems. They will increasingly encourage the practice of "sustainable agriculture" by developing and implementing plans to manage pests, crops, soil fertility and erosion, and animal waste in ways that reduce the use of harmful chemicals and do little damage to the natural environment. Also, an expanding population and an increasing public focus on diet, health, and food safety will result in job opportunities for food scientists and technologists.

Graduates with advanced degrees will be in the best position to enter jobs as agricultural scientists. Bachelor's degree holders can work in some applied research and product development positions, but usually only in certain subfields, such as food science and technology. Also, the Federal Government hires bachelor's degree holders to work as soil scientists. Despite the more limited opportunities for those with only a bachelor's degree to obtain jobs as agricultural scientists, a bachelor's degree in agricultural science is useful for managerial jobs in businesses that deal with ranchers and farmers, such as feed, fertilizer, seed, and farm equipment manufacturers; retailers or wholesalers; and farm credit institutions. Four-year degrees also may help persons enter occupations such as farmer, or farm or ranch manager; cooperative extension service agent; agricultural products inspector; or purchasing or sales agent for agricultural commodity or farm supply companies.

Earnings

Median annual earnings of agricultural and food scientists were \$52,160 in 2000. The middle 50 percent earned between \$40,720 and \$66,370. The lowest 10 percent earned less than \$31,910, and the highest 10 percent earned more than \$83,740.

Average Federal salaries for employees in nonsupervisory, supervisory and managerial positions in certain agricultural science specialties in 2001 were as follows: Animal science, \$76,582; agronomy, \$62,311; soil science, \$58,878; horticulture, \$59,472; and entomology, \$70,133.

According to the National Association of Colleges and Employers, beginning salary offers in 2001 for graduates with a bachelor's degree in animal science averaged \$28,031 a year.

Related Occupations

The work of agricultural scientists is closely related to that of biologists and other natural scientists, such as chemists, conservation scientists, and foresters. It is also related to managers of agricultural production, such as farmers, ranchers, agricultural managers. Certain specialties of agricultural science also are related to other occupations. For example, the work of animal scientists is related to that of veterinarians and horticulturists perform duties similar to those of landscape architects.

Sources of Additional Information

Information on careers in agricultural science is available from:

- American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711-1086.
- Food and Agricultural Careers for Tomorrow, Purdue University, 1140 Agricultural Administration Bldg., West Lafayette, IN 47907-1140.

For information on careers in food technology, write to:

- Institute of Food Technologists, Suite 300, 221 N. LaSalle St., Chicago IL 60601-1291.

Information on acquiring a job as an agricultural scientist with the Federal Government is available from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the Internet site: <http://www.usajobs.opm.gov>.

Architects, Except Landscape and Naval

(O*NET 17-1011.00)

Significant Points

- More than 28 percent were self-employed—about four times the proportion for all professional and related occupations.
- Licensing requirements include a professional degree in architecture, a period of practical training and the passing of all divisions of the Architect Registration Examination.
- Architecture graduates may face competition, especially for jobs in the most prestigious firms; experience from working in a firm during school and knowledge of computer-aided design and drafting technology are advantages.

Nature of the Work

People need places in which to live, work, play, learn, worship, meet, govern, shop, eat. These places may be private or public; indoors or out; rooms, buildings, or complexes, and together comprise neighborhoods, towns, suburbs and cities. *Architects*—licensed professionals trained in the art and science of building design—transform these needs into concepts and then develop the concepts into building images and plans that can be constructed by others.

Architects design the overall aesthetic and functional look of buildings and other structures. The design of a building involves far more than its appearance. Buildings also must be functional, safe, and economical, and must suit the needs of the people who use them. Architects take all these things into consideration when they design buildings and other structures.

Architects provide professional services to individuals and organizations planning a construction project. They may be involved in all phases of development, from the initial discussion with the client through the entire construction process. Their duties require specific skills—designing, engineering, managing, supervising, and communicating with clients and builders.

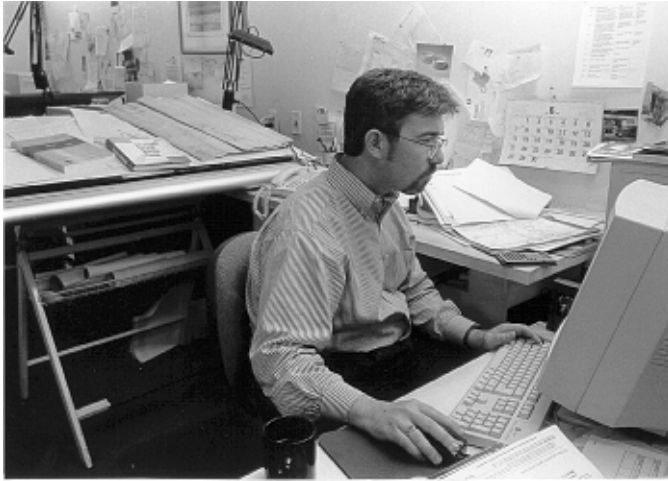
The architect and client discuss the objectives, requirements, and budget of a project. In some cases, architects provide various predesign services—conducting feasibility and environmental impact studies, selecting a site, or specifying the requirements the design must meet. For example, they may determine space requirements by researching the number and type of potential users of a building. The architect then prepares drawings and a report presenting ideas for the client to review.

After the initial proposals are discussed and accepted, architects develop final construction plans. These plans show the building's appearance and details for its construction. Accompanying these are drawings of the structural system; air-conditioning, heating, and ventilating systems; electrical systems; plumbing; and possibly site and landscape plans. They also specify the building materials and, in some cases, the interior furnishings. In developing designs, architects follow building codes, zoning laws, fire regulations, and other ordinances, such as those requiring easy access by disabled persons. Throughout the planning stage, they make necessary changes. Although they have traditionally used pencil and paper to produce design and construction drawings, architects are increasingly turning to computer-aided design and drafting (CADD) technology for these important tasks.

Architects may also assist the client in obtaining construction bids, selecting a contractor, and negotiating the construction contract. As construction proceeds, they may visit the building site to ensure the contractor is following the design, adhering to the schedule, using the specified materials, and meeting quality work standards. The job is not complete until all construction is finished, required tests are made, and construction costs are paid. Sometimes, architects also provide postconstruction services, such as facilities management. They advise on energy efficiency measures, evaluate how well the building design adapts to the needs of occupants, and make necessary improvements.

Architects design a wide variety of buildings, such as office and apartment buildings, schools, churches, factories, hospitals, houses, and airport terminals. They also design complexes such as urban centers, college campuses, industrial parks, and entire communities. They also may advise on the selection of building sites, prepare cost analysis and land-use studies, and do long-range planning for land development.

Architects sometimes specialize in one phase of work. Some specialize in the design of one type of building—for example, hospitals, schools, or housing. Others focus on planning and predesign services or construction management, and do minimal design work.



Architects increasingly use computer-aided design and drafting technology to produce design and construction drawings.

They often work with engineers, urban planners, interior designers, landscape architects, and other professionals. In fact, architects spend a great deal of their time in coordinating information from, and the work of, others engaged in the same project. Consequently, architects—particularly at larger firms—are now using the Internet to update designs and communicate changes for the sake of speed and cost savings.

During the required training period leading up to licensing as architects, entry-level workers are called interns. This training period, which generally lasts 3 years, gives them practical work experience which aids interns in preparing for the Architect Registration Examination (ARE). Typical duties may include preparing construction drawings on CADD, building models, or assisting in the design of one part of a project.

Working Conditions

Architects usually work in a comfortable environment. Most of their time is spent in offices consulting with clients, developing reports and drawings, and working with other architects and engineers. However, they often visit construction sites to review the progress of projects.

Architects may occasionally be under stress, working nights and weekends to meet deadlines. In 2000, almost half of all architects worked more than 40 hours a week, in contrast to about 1 in 4 workers in all occupations combined.

Employment

Architects held about 102,000 jobs in 2000. The majority of jobs were in architectural firms—most of which employ fewer than 5 workers. A few worked for general building contractors, and for government agencies responsible for housing, planning, or community development, such as the U.S. Departments of Defense and Interior, and the General Services Administration. Nearly 3 in 10 architects were self-employed.

Training, Other Qualifications, and Advancement

All States and the District of Columbia require individuals to be licensed (registered) before they may call themselves architects or contract to provide architectural services. Nevertheless, many architecture school graduates work in the field while they are in the process of becoming licensed. However, a licensed architect is required to take legal responsibility for all work. Licensing

requirements include a professional degree in architecture, a period of practical training or internship, and passage of all divisions of the ARE.

In most States, the professional degree in architecture must be from one of the 111 schools of architecture with degree programs accredited by the National Architectural Accrediting Board (NAAB). However, State architectural registration boards set their own standards, so graduation from a nonNAAB-accredited program may meet the educational requirement for licensing in a few States. Three types of professional degrees in architecture are available through colleges and universities. The majority of all architectural degrees are from 5-year Bachelor of Architecture programs, intended for students entering from high school or with no previous architectural training. In addition, a number of schools offer a 2-year Master of Architecture program for students with a preprofessional undergraduate degree in architecture or a related area, or a 3- or 4-year Master of Architecture program for students with a degree in another discipline.

The choice of degree type depends upon each individual's preference and educational background. Prospective architecture students should consider the available options before committing to a program. For example, although the 5-year Bachelor of Architecture program offers the fastest route to the professional degree, courses are specialized and, if the student does not complete the program, transferring to a nonarchitectural program may be difficult. A typical program includes courses in architectural history and theory, building design, structures, technology, construction methods, professional practice, math, physical sciences, and liberal arts. Central to most architectural programs is the design studio, where students put into practice the skills and concepts learned in the classroom. During the final semester of many programs, students devote their studio time to creating an architectural project from beginning to end, culminating in a 3-dimensional model of their design.

Many schools of architecture also offer post-professional degrees for those who already have a bachelor's or master's degree in architecture or other areas. Although graduate education beyond the professional degree is not required for practicing architects, it may be for research, teaching, and certain specialties.

Architects must be able to visually communicate their ideas to clients. Artistic and drawing ability is very helpful in doing this, but not essential. More important are a visual orientation and the ability to conceptualize and understand spatial relationships. Good communication skills, the ability to work independently or as part of a team, and creativity are important qualities for anyone interested in becoming an architect. Computer literacy also is required as most firms use computers for writing specifications, 2- and 3-dimensional drafting, and financial management. Knowledge of computer-aided design and drafting (CADD) is helpful and will become essential as architectural firms continue to adopt this technology. Recently, the profession recognized National CAD Standards (NCS); architecture students who master NCS may have an advantage in the job market.

All State architectural registration boards require a training period before candidates may sit for the ARE and become licensed. Most States have adopted the training standards established by the Intern Development Program, a program of the American Institute of Architects and the National Council of Architectural Registration Boards (NCARB). These standards stipulate broad and diversified training under the supervision of a licensed architect over a 3-year period. New graduates usually begin as intern-architects in architectural firms, where they assist in preparing architectural documents or drawings. They also may do research on building codes and materials, or write specifications for building materials,

installation criteria, the quality of finishes, and other related details. Graduates with degrees in architecture also enter related fields such as graphic, interior, or industrial design; urban planning; real estate development; civil engineering; or construction management. After completing the on-the-job training period, interns are eligible to sit for the ARE. The examination tests candidates for their knowledge, skills, and ability to provide the various services required in the design and construction of buildings. Candidates who pass the ARE and meet all standards established by their State board are licensed to practice in that State.

After becoming licensed and gaining experience, architects take on increasingly responsible duties, eventually managing entire projects. In large firms, architects may advance to supervisory or managerial positions. Some architects become partners in established firms; others set up their own practice.

Several States require continuing education to maintain a license, and many more States are expected to adopt mandatory continuing education. Requirements vary by State, but usually involve the completion of a certain number of credits every year or two through seminars, workshops, formal university classes, conferences, self-study courses, or other sources. A growing number of architects voluntarily seek certification by NCARB, which can facilitate their getting licensed to practice in additional States. Certification is awarded after independent verification of the applying architect's educational transcripts, employment record, and professional references. It is the primary requirement for reciprocity of licensing among State Boards that are NCARB members.

Job Outlook

Prospective architects may face competition for entry-level positions, especially if the number of architectural degrees awarded remains at current levels or increases. Employment of architects is projected to grow about as fast as the average for all occupations through 2010 and additional job openings will stem from the need to replace architects who retire or leave the labor force for other reasons. However, many individuals are attracted to this occupation, and the number of applicants often exceeds the number of available jobs, especially in the most prestigious firms. Prospective architects who gain career-related experience in an architectural firm while in school and who know CADD technology (especially that which conforms to the new national standards) will have a distinct advantage in obtaining an intern-architect position after graduation.

Employment of architects is strongly tied to the level of local construction, particularly nonresidential structures such as office buildings, shopping centers, schools, and healthcare facilities. After a boom in nonresidential construction during the 1980s, building slowed significantly during the first half of the 1990s. This trend is expected to continue because of slower labor force growth and increases in telecommuting and flexiplace work. However, as the stock of buildings ages, demand for remodeling and repair work should grow considerably. The needed renovation and rehabilitation of old buildings, particularly in urban areas where space for new buildings is becoming limited, is expected to provide many job opportunities for architects. In addition, demographic trends and changes in healthcare delivery are influencing the demand for certain institutional structures, and should also provide more jobs for architects in the future. For example, increases in the school-age population have resulted in new school construction. Additions to existing schools (especially colleges and universities), as well as overall modernization, will continue to add to demand for architects through 2010. Growth is expected in the number of adult care centers, assisted-living facilities, and community health clinics, all of which are preferable, less costly alternatives to hospitals and nursing homes.

Because construction—particularly office and retail—is sensitive to cyclical changes in the economy, architects will face particularly strong competition for jobs or clients during recessions, and layoffs may occur. Those involved in the design of institutional buildings such as schools, hospitals, nursing homes, and correctional facilities will be less affected by fluctuations in the economy.

Even in times of overall good job opportunities, however, there may be areas of the country with poor opportunities. Architects who are licensed to practice in one State must meet the licensing requirements of other States before practicing elsewhere. Obtaining licensure in other States, after initially receiving licensure in one State, is known as “reciprocity”, and is much easier if an architect has received certification from the National Council of Architectural Registration Boards.

Earnings

Median annual earnings of architects were \$52,510 in 2000. The middle 50 percent earned between \$41,060 and \$67,720. The lowest 10 percent earned less than \$32,540 and the highest 10 percent earned more than \$85,670.

Earnings of partners in established architectural firms may fluctuate because of changing business conditions. Some architects may have difficulty establishing their own practices and may go through a period when their expenses are greater than their income, requiring substantial financial resources.

Related Occupations

Architects design buildings and related structures. Construction managers, like architects, are also engaged in the planning and coordinating of activities concerned with the construction and maintenance of buildings and facilities. Others who engage in similar work are landscape architects, civil engineers, urban and regional planners, and designers, including interior designers, commercial and industrial designers, and graphic designers.

Sources of Additional Information

Information about education and careers in architecture can be obtained from:

- Practice Management Professional Interest Area, The American Institute of Architects, 1735 New York Ave. NW., Washington, DC 20006. Internet: <http://www.aiaonline.com>
- Intern Development Program, National Council of Architectural Registration Boards, Suite 1100K, 1801 K Street NW., Washington, D.C. 20006-1310. Internet: <http://www.ncarb.org>
- Consortium for Design and Construction Careers, P.O. Box 1515, Oak Park, IL 60304-1515. Internet: <http://www.archcareers.net>

Atmospheric Scientists

(O*NET 19-2021.00)

Significant Points

- The Federal Government employs more than 4 out of 10 atmospheric scientists and is their largest employer.
- A bachelor's degree in meteorology, or in a closely related field with courses in meteorology, is the minimum educational requirement; a master's degree is necessary for some positions, and a Ph.D. is required for most research positions.
- Applicants may face competition for jobs if the number of degrees awarded in atmospheric science and meteorology remain near current levels.

Nature of the Work

Atmospheric science is the study of the atmosphere—the blanket of air covering the Earth. *Atmospheric scientists*, commonly called *meteorologists*, study the atmosphere's physical characteristics, motions, and processes, and the way it affects the rest of our environment. The best known application of this knowledge is in forecasting the weather. However, weather information and meteorological research are also applied in air-pollution control, agriculture, air and sea transportation, defense, and the study of trends in Earth's climate such as global warming, droughts, or ozone depletion.

Atmospheric scientists who forecast the weather, known professionally as *operational meteorologists*, are the largest group of specialists. They study information on air pressure, temperature, humidity, and wind velocity; and apply physical and mathematical relationships to make short- and long-range weather forecasts. Their data come from weather satellites, weather radars, and sensors and observers in many parts of the world. Meteorologists use sophisticated computer models of the world's atmosphere to make long-term, short-term, and local-area forecasts. These forecasts inform not only the general public, but also those who need accurate weather information for both economic and safety reasons, as in the shipping, air transportation, agriculture, fishing, and utilities industries.

The use of weather balloons, launched a few times a day to measure wind, temperature, and humidity in the upper atmosphere, is



Atmospheric scientists commonly use atmospheric charts and graphs for analysis and prediction of weather systems.

currently supplemented by sophisticated atmospheric monitoring equipment that transmits data as frequently as every few minutes. Doppler radar, for example, can detect airflow patterns in violent storm systems—allowing forecasters to better predict tornadoes and other hazardous winds, as well as to monitor the storm's direction and intensity. Combined radar and satellite observations allow meteorologists to predict flash floods.

Some atmospheric scientists work in research. *Physical meteorologists*, for example, study the atmosphere's chemical and physical properties; the transmission of light, sound, and radio waves; and the transfer of energy in the atmosphere. They also study factors affecting the formation of clouds, rain, snow, and other weather phenomena, such as severe storms. *Synoptic meteorologists* develop new tools for weather forecasting using computers and sophisticated mathematical models. *Climatologists* collect, analyze, and interpret past records of wind, rainfall, sunshine, and temperature in specific areas or regions. Their studies are used to design buildings, plan heating and cooling systems, and aid in effective land use and agricultural production. Other research meteorologists examine the most effective ways to control or diminish air pollution.

Working Conditions

Most weather stations operate around the clock 7 days a week. Jobs in such facilities usually involve night, weekend, and holiday work, often with rotating shifts. During weather emergencies, such as hurricanes, operational meteorologists may work overtime. Operational meteorologists are also often under pressure to meet forecast deadlines. Weather stations are found all over—at airports, in or near cities, and in isolated and remote areas. Some atmospheric scientists also spend time observing weather conditions and collecting data from aircraft. Weather forecasters who work for radio or television stations broadcast their reports from station studios, and may work evenings and weekends. Meteorologists in smaller weather offices often work alone; in larger ones, they work as part of a team. Meteorologists not involved in forecasting tasks work regular hours, usually in offices. Those who work for private consulting firms or for companies analyzing and monitoring emissions to improve air quality usually work with other scientists or engineers.

Employment

Atmospheric scientists held about 6,900 jobs in 2000. The Federal Government is the largest single employer of civilian meteorologists, employing about 3,000. The National Oceanic and Atmospheric Administration (NOAA) employed most Federal meteorologists in the National Weather Service stations throughout the Nation; the remainder of NOAA's meteorologists worked mainly in research and development or management. The Department of Defense employed several hundred civilian meteorologists. Others worked for research and testing services, private weather consulting services, radio and television broadcasting, air carriers, and computer and data processing services.

Although several hundred people teach atmospheric science and related courses in college and university departments of meteorology or atmospheric science, physics, earth science, and geophysics, these individuals are classified as college or university faculty, rather than atmospheric scientists. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

In addition to civilian meteorologists, hundreds of Armed Forces members are involved in forecasting and other meteorological work. (See the statement on job opportunities in the Armed Forces elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

A bachelor's degree in meteorology or atmospheric science, or in a closely related field with courses in meteorology, usually is the minimum educational requirement for an entry-level position as an atmospheric scientist.

The preferred educational requirement for entry-level meteorologists in the Federal Government is a bachelor's degree—not necessarily in meteorology—but with at least 24 semester hours of meteorology courses, including 6 hours in the analysis and prediction of weather systems and 2 hours of remote sensing of the atmosphere or instrumentation. Other required courses include differential and integral calculus, differential equations, 6 hours of college physics, and at least 9 hours of courses appropriate for a physical science major—such as statistics, computer science, chemistry, physical oceanography, or physical climatology. Sometimes, a combination of experience and education may be substituted for a degree.

Although positions in operational meteorology are available for those with only a bachelor's degree, obtaining a master's degree enhances employment opportunities and advancement potential. A master's degree usually is necessary for conducting applied research and development, and a Ph.D. is required for most basic research positions. Students planning on a career in research and development need not necessarily major in atmospheric science or meteorology as an undergraduate. In fact, a bachelor's degree in mathematics, physics, or engineering provides excellent preparation for graduate study in atmospheric science.

Because atmospheric science is a small field, relatively few colleges and universities offer degrees in meteorology or atmospheric science, although many departments of physics, earth science, geography, and geophysics offer atmospheric science and related courses. Prospective students should make certain that courses required by the National Weather Service and other employers are offered at the college they are considering. Computer science courses, additional meteorology courses, a strong background in mathematics and physics, and good communication skills are important to prospective employers. Many programs combine the study of meteorology with another field, such as agriculture, oceanography, engineering, or physics. For example, hydrometeorology is the blending of hydrology (the science of Earth's water) and meteorology, and is the field concerned with the effect of precipitation on the hydrologic cycle and the environment. Students who wish to become broadcast meteorologists for radio or television stations should develop excellent communication skills through courses in speech, journalism, and related fields. Those interested in air quality work should take courses in chemistry and supplement their technical training with coursework in policy or government affairs.

Beginning atmospheric scientists often do routine data collection, computation, or analysis, and some basic forecasting. Entry-level operational meteorologists in the Federal Government usually are placed in intern positions for training and experience. During this period, they learn about the Weather Service's forecasting equipment and procedures, and rotate to different offices to learn about various weather systems. After completing the training period, they are assigned a permanent duty station. Experienced meteorologists may advance to supervisory or administrative jobs, or may handle more complex forecasting jobs. After several years of experience, some meteorologists establish their own weather consulting services.

The American Meteorological Society offers professional certification of consulting meteorologists, administered by a Board of Certified Consulting Meteorologists. Applicants must meet formal education requirements (though not necessarily have a college

degree), pass an examination to demonstrate thorough meteorological knowledge, have a minimum of 5 years of experience or a combination of experience plus an advanced degree, and provide character references from fellow professionals.

Job Outlook

Employment of atmospheric scientists is projected to increase about as fast as the average for all occupations through 2010, but prospective atmospheric scientists may face competition if the number of degrees awarded in atmospheric science and meteorology remain near current levels. The National Weather Service (NWS) has completed an extensive modernization of its weather forecasting equipment and finished all hiring of meteorologists needed to staff the upgraded stations. The NWS has no plans to increase the number of weather stations or the number of meteorologists in existing stations for many years. Employment of meteorologists in other Federal agencies is expected to decline slightly as efforts to reduce the Federal Government workforce continue.

On the other hand, job opportunities for atmospheric scientists in private industry are expected to be better than in the Federal Government over the 2000-10 period. As research leads to continuing improvements in weather forecasting, demand should grow for private weather consulting firms to provide more detailed information than has formerly been available, especially to weather-sensitive industries. Farmers, commodity investors, radio and television stations, and utilities, transportation, and construction firms can greatly benefit from additional weather information more closely targeted to their needs than the general information provided by the National Weather Service. Additionally, research on seasonal and other long-range forecasting is yielding positive results, which should spur demand for more atmospheric scientists to interpret these forecasts and advise weather-sensitive industries. However, because many customers for private weather services are in industries sensitive to fluctuations in the economy, the sales and growth of private weather services depend on the health of the economy.

There will continue to be demand for atmospheric scientists to analyze and monitor the dispersion of pollutants into the air to ensure compliance with Federal environmental regulations outlined in the Clean Air Act of 1990, but employment increases are expected to be small.

Earnings

Median annual earnings of atmospheric scientists in 2000 were \$58,510. The middle 50 percent earned between \$39,780 and \$72,740. The lowest 10 percent earned less than \$29,880, and the highest 10 percent earned more than \$89,060.

The average salary for meteorologists in nonsupervisory, supervisory, and managerial positions employed by the Federal Government was about \$68,100 in 2001. Meteorologists in the Federal Government with a bachelor's degree and no experience received a starting salary of \$24,245 or \$29,440, depending on their college grades. Those with a master's degree could start at \$29,440 or \$36,606; those with the Ph.D., at \$47,039 or \$59,661. Beginning salaries for all degree levels are slightly higher in selected areas of the country where the prevailing local pay level is higher.

Related Occupations

Workers in other occupations concerned with the physical environment include environmental scientists and geoscientists, physicists and astronomers, mathematicians, and civil, chemical, and environmental engineers.

Sources of Additional Information

Information about careers in meteorology is available from:

► American Meteorological Society, 45 Beacon St., Boston, MA 02108.
Internet: <http://www.ametsoc.org/AMS>

Information on obtaining a meteorologist position with the Federal Government is available from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the Internet site: <http://www.usajobs.opm.gov>.

Biological and Medical Scientists

(O*NET 19-1021.01, 19-1021.02, 19-1022.00, 19-1023.00, 19-1029.99, 19-1041.00, 19-1042.00, 19-1099.99)

Significant Points

- A Ph.D. degree usually is required for independent research, but a master's degree is sufficient for some jobs in applied research or product development; a bachelor's degree is adequate for some nonresearch jobs.
- Medical scientist jobs require a Ph.D. degree in a biological science, but some jobs need a medical degree.
- Doctoral degree holders face considerable competition for independent research positions; holders of bachelor's or master's degrees in biological science can expect better opportunities in nonresearch positions.

Nature of the Work

Biological and medical scientists study living organisms and their relationship to their environment. They research problems dealing with life processes. Most specialize in some area of biology such as zoology (the study of animals) or microbiology (the study of microscopic organisms).

Many biological scientists and virtually all medical scientists work in research and development. Some conduct basic research to advance knowledge of living organisms, including viruses, bacteria, and other infectious agents. Past research has resulted in the development of vaccines, medicines, and treatments for cancer and other diseases. Basic biological and medical research continues to provide the building blocks necessary to develop solutions to human health problems, and to preserve and repair the natural environment. Biological and medical scientists mostly work independently in private industry, university, or government laboratories, often exploring new areas of research or expanding on specialized research started in graduate school. Those who are not wage and salary workers in private industry typically submit grant proposals to obtain funding for their projects. Colleges and universities, private industry, and Federal Government agencies, such as the National Institutes of Health and the National Science Foundation, contribute to the support of scientists whose research proposals are determined to be financially feasible and have the potential to advance new ideas or processes.

Biological and medical scientists who work in applied research or product development use knowledge provided by basic research

to develop new drugs and medical treatments, increase crop yields, and protect and clean up the environment. They usually have less autonomy than basic researchers to choose the emphasis of their research, relying instead on market-driven directions based on the firm's products and goals. Biological and medical scientists doing applied research and product development in private industry may be required to express their research plans or results to nonscientists who are in a position to veto or approve their ideas, and they must understand the business impact of their work. Scientists increasingly are working as part of teams, interacting with engineers, scientists of other disciplines, business managers, and technicians. Some biological and medical scientists also work with customers or suppliers, and manage budgets.

Those who conduct research usually work in laboratories and use electron microscopes, computers, thermal cyclers, or a wide variety of other equipment. Some conduct experiments using laboratory animals or greenhouse plants. This is particularly true of botanists, physiologists, and zoologists. For some biological scientists, a good deal of research is performed outside of laboratories. For example, a botanist may do research in tropical rain forests to see what plants grow there, or an ecologist may study how a forest area recovers after a fire.

Some biological and medical scientists work in managerial or administrative positions, usually after spending some time doing research and learning about the firm, agency, or project. They may plan and administer programs for testing foods and drugs, for example, or direct activities at zoos or botanical gardens. Some work as consultants to business firms or to government, while others test and inspect foods, drugs, and other products.

In the 1980s, swift advances in basic biological knowledge related to genetics and molecules spurred growth in the field of biotechnology. Biological and medical scientists using this technology manipulate the genetic material of animals or plants, attempting to make organisms more productive or resistant to disease. Research using biotechnology techniques, such as recombining DNA, has led to the discovery of important drugs, including human insulin and growth hormone. Many other substances not previously available in large quantities are starting to be produced by biotechnological means; some may be useful in treating cancer and other diseases. Today, many of these scientists are involved in biotechnology, including those who work on the Human Genome project, isolating, identifying, and sequencing human genes and then determining their functionality. This work continues to lead to the discovery of the genes associated with specific diseases and inherited traits, such as certain types of cancer or obesity. These advances in biotechnology have opened up research opportunities in almost all areas of biology, including commercial applications in agriculture, environmental remediation, and the food and chemical industries.

Most biological scientists who come under the category of *biologist* are further classified by the type of organism they study or by the specific activity they perform, although recent advances in the understanding of basic life processes at the molecular and cellular levels have blurred some traditional classifications.

Aquatic biologists study plants and animals living in water. *Marine biologists* study salt water organisms, and *limnologists* study fresh water organisms. Marine biologists are sometimes mistakenly called oceanographers, but oceanography is the study of the physical characteristics of oceans and the ocean floor. (See the statement on environmental scientists and geoscientists elsewhere in the *Handbook*.)

Biochemists study the chemical composition of living things. They analyze the complex chemical combinations and reactions involved in metabolism, reproduction, growth, and heredity.

Biochemists and molecular biologists do most of their work in biotechnology, which involves understanding the complex chemistry of life.

Botanists study plants and their environment. Some study all aspects of plant life; others specialize in areas such as identification and classification of plants, the structure and function of plant parts, the biochemistry of plant processes, the causes and cures of plant diseases, and the geological record of plants.

Microbiologists investigate the growth and characteristics of microscopic organisms such as bacteria, algae, or fungi. *Medical microbiologists* study the relationship between organisms and disease or the effect of antibiotics on microorganisms. Other microbiologists specialize in environmental, food, agricultural, or industrial microbiology, virology (the study of viruses), or immunology (the study of mechanisms that fight infections). Many microbiologists use biotechnology to advance knowledge of cell reproduction and human disease.

Physiologists study life functions of plants and animals, both in the whole organism and at the cellular or molecular level, under normal and abnormal conditions. Physiologists often specialize in functions such as growth, reproduction, photosynthesis, respiration, or movement, or in the physiology of a certain area or system of the organism.

Biophysicists study the application of principles of physics, such as electrical and mechanical energy and related phenomena, to living cells and organisms.



Biological scientists who study plants and animals living in water are called aquatic biologists.

Zoologists and wildlife biologists study animals and wildlife—their origin, behavior, diseases, and life processes. Some experiment with live animals in controlled or natural surroundings while others dissect dead animals to study their structure. They may also collect and analyze biological data to determine the environmental effects of current and potential use of land and water areas. Zoologists usually are identified by the animal group studied—ornithologists (birds), mammalogists (mammals), herpetologists (reptiles), and ichthyologists (fish).

Ecologists study the relationships among organisms and between organisms and their environments and the effects of influences such as population size, pollutants, rainfall, temperature, and altitude. Utilizing knowledge of various scientific disciplines, they may collect, study, and report data on air, food, soil, and water.

Soil scientists study soil characteristics, map soil types, and investigate responses of soil to determine its capabilities and productivity.

Agricultural and food scientists, who are sometimes referred to as biological scientists, are included in a separate statement elsewhere in the *Handbook*.

Biological scientists who do biomedical research are usually called *medical scientists*. Medical scientists work on basic research into normal biological systems to understand the causes of and to discover treatment for disease and other health problems. Medical scientists try to identify changes in a cell, chromosome, or even gene that signal the development of medical problems, such as different types of cancer. After identifying structures of or changes in organisms that provide clues to health problems, medical scientists work on the treatment of problems. For example, a medical scientist involved in cancer research may formulate a combination of drugs that will lessen the effects of the disease. Medical scientists with a medical degree can administer these drugs to patients in clinical trials, monitor their reactions, and observe the results. (Medical scientists without a medical degree normally collaborate with a medical doctor who deals directly with patients.) The medical scientist will return to the laboratory to examine the results and, if necessary, adjust the dosage levels to reduce negative side effects or to try to induce even better results. In addition to using basic research to develop treatments for health problems, medical scientists attempt to discover ways to prevent health problems from developing, such as affirming the link between smoking and increased risk of lung cancer, or between alcoholism and liver disease.

Working Conditions

Biological and medical scientists usually work regular hours in offices or laboratories and usually are not exposed to unsafe or unhealthy conditions. Those who work with dangerous organisms or toxic substances in the laboratory must follow strict safety procedures to avoid contamination. Medical scientists also spend time working in clinics and hospitals administering drugs and treatments to patients in clinical trials. Many biological scientists such as botanists, ecologists, and zoologists take field trips that involve strenuous physical activity and primitive living conditions.

Some biological and medical scientists depend on grant money to support their research. They may be under pressure to meet deadlines and to conform to rigid grant-writing specifications when preparing proposals to seek new or extended funding.

Employment

Biological and medical scientists held about 138,000 jobs in 2000; about half were biological scientists. Four in ten biological scientists were employed by Federal, State, and local governments. Federal biological scientists worked mainly in the U.S. Departments of

Agriculture, the Interior, and Defense, and in the National Institutes of Health. Most of the rest worked in the drug industry, which includes pharmaceutical and biotechnology establishments, hospitals, or research and testing laboratories. About 1 in 8 medical scientists worked in Government, with most of the remainder found in research and testing laboratories, educational institutions, the drug industry, and hospitals.

In addition, many biological and medical scientists held biology faculty positions in colleges and universities. (See the statement on teachers—postsecondary elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

For biological scientists, the Ph.D. degree usually is necessary for independent research and for advancement to administrative positions. A master's degree is sufficient for some jobs in applied research or product development and for jobs in management, inspection, sales, and service. The bachelor's degree is adequate for some nonresearch jobs. For example, some graduates with a bachelor's degree start as biological scientists in testing and inspection, or get jobs related to biological science, such as technical sales or service representatives. In some cases, graduates with a bachelor's degree are able to work in a laboratory environment on their own projects, but this is unusual. Some may work as research assistants. Others become biological technicians, medical laboratory technologists or, with courses in education, high school biology teachers. (See the statements on clinical laboratory technologists and technicians; science technicians; and teachers—preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook*.) Many with a bachelor's degree in biology enter medical, dental, veterinary, or other health profession schools.

In addition to required courses in chemistry and biology, undergraduate biological science majors usually study allied disciplines such as mathematics, physics, and computer science. Computer courses are essential, as employers increasingly prefer job applicants who are able to apply computer skills to modeling and simulation tasks and to operate computerized laboratory equipment. Those interested in studying the environment also should take courses in environmental studies and become familiar with current legislation and regulations.

Most colleges and universities offer bachelor's degrees in biological science and many offer advanced degrees. Curriculums for advanced degrees often emphasize a subfield such as microbiology or botany, but not all universities offer all curriculums. Advanced degree programs include classroom and fieldwork, laboratory research, and a thesis or dissertation. Biological scientists who have advanced degrees often take temporary postdoctoral research positions that provide specialized research experience. In private industry, some may become managers or administrators within the field of biology; others leave biology for nontechnical managerial, administrative, or sales jobs.

Biological scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Those in private industry, especially those who aspire to management or administrative positions, should possess strong business and communication skills and be familiar with regulatory issues and marketing and management techniques. Those doing field research in remote areas must have physical stamina.

The Ph.D. degree in a biological science is the minimum education required for prospective medical scientists because the work of medical scientists is almost entirely research oriented. A Ph.D. degree qualifies one to do research on basic life processes or on

particular medical problems or diseases, and to analyze and interpret the results of experiments on patients. Medical scientists who administer drug or gene therapy to human patients, or who otherwise interact medically with patients—such as drawing blood, excising tissue, or performing other invasive procedures—must have a medical degree. It is particularly helpful for medical scientists to earn both Ph.D. and medical degrees.

In addition to formal education, medical scientists usually spend several years in a postdoctoral position before they apply for permanent jobs. Postdoctoral work provides valuable laboratory experience, including experience in specific processes and techniques, such as gene splicing, which are transferable to other research projects. In some institutions, the postdoctoral position can lead to a permanent position.

Job Outlook

Despite prospects of faster-than-average job growth for biological and medical scientists over the 2000-10 period, doctoral degree holders can expect to face considerable competition for basic research positions. The Federal Government funds much basic research and development, including many areas of medical research. Recent budget tightening has led to smaller increases in Federal basic research and development expenditures, further limiting the dollar amount of each grant, although the number of grants awarded to researchers remains fairly constant. At the same time, the number of newly trained scientists has continued to increase at a steady rate, so both new and established scientists have experienced greater difficulty winning and renewing research grants. If the number of advanced degrees awarded continues to grow unabated, this competitive scenario is likely to persist. Additionally, applied research positions in private industry may become more difficult to obtain if more scientists seek jobs in private industry than have done so in the past due to the competitive job market for college and university faculty.

Opportunities for those with a bachelor's or master's degree in biological science are expected to be better. The number of science-related jobs in sales, marketing, and research management, for which non-Ph.D.s usually qualify, are expected to be more plentiful than independent research positions. Non-Ph.D.s also may fill positions as science or engineering technicians or health technologists and technicians. Some become high school biology teachers, while those with a doctorate in biological science may become college and university faculty.

Biological and medical scientists enjoyed very rapid gains in employment between the mid-1980s and mid-1990s, in part reflecting increased staffing requirements in new biotechnology companies. Employment growth should slow somewhat as increases in the number of new biotechnology firms slow and existing firms merge or are absorbed into larger ones. However, much of the basic biological research done in recent years has resulted in new knowledge, including the isolation and identification of new genes. Biological and medical scientists will be needed to take this knowledge to the next stage, which is the understanding of how certain genes function within an entire organism, so that gene therapies can be developed to treat diseases. Even pharmaceutical and other firms not solely engaged in biotechnology are expected to increasingly use biotechnology techniques, spurring employment increases for biological and medical scientists. In addition, efforts to discover new and improved ways to clean up and preserve the environment will continue to add to growth. More biological scientists will be needed to determine the environmental impact of industry and government actions and to prevent or correct environmental problems. Expected expansion in research related to health issues

such as AIDS, cancer, and Alzheimer's disease also should result in employment growth.

Biological and medical scientists are less likely to lose their jobs during recessions than are those in many other occupations because many are employed on long-term research projects. However, a recession could further influence the amount of money allocated to new research and development efforts, particularly in areas of risky or innovative research. A recession could also limit the possibility of extension or renewal of existing projects.

Earnings

Median annual earnings of biological scientists were \$49,239 in 2000. Median annual earnings of medical scientists were \$57,196 in 2000, with epidemiologists earning \$48,390 and medical scientists, except epidemiologists, earning \$57,810. Median annual earnings of medical scientists were \$54,260 in research and testing laboratories and \$41,010 in hospitals in 1999.

According to the National Association of Colleges and Employers, beginning salary offers in 2000 averaged \$29,235 a year for bachelor's degree recipients in biological science, \$35,667 for master's degree recipients, and \$42,744 for doctoral degree recipients.

In the Federal Government in 2001, general biological scientists in nonsupervisory, supervisory, and managerial positions earned an average salary of \$61,236; microbiologists, \$67,835; ecologists, \$61,936; physiologists, \$78,366; and geneticists, \$72,510.

Related Occupations

Many other occupations deal with living organisms and require a level of training similar to that of biological and medical scientists. These include agricultural and food scientists, and conservation scientists and foresters, as well as health occupations such as physicians and surgeons, dentists, and veterinarians.

Sources of Additional Information

For information on careers in the biological sciences, contact:

► American Institute of Biological Sciences, Suite 200, 1444 I St. NW., Washington, DC 20005. Internet: <http://www.aibs.org>

For information on careers in physiology, contact:

► American Physiological Society, Education Office, 9650 Rockville Pike, Bethesda, MD 20814. Internet: <http://www.the-aps.org>

For information on careers in biochemistry or biological sciences, contact:

► Federation of American Societies for Experimental Biology, 9650 Rockville Pike, Bethesda, MD 20814. Internet: <http://www.faseb.org>

For a brochure entitled *Is a Career in the Pharmaceutical Sciences Right for Me?*, contact:

► American Association of Pharmaceutical Scientists (AAPS), 2107 Wilson Blvd., Suite #700, Arlington, VA 22201. Internet: <http://www.aaps.org/sciaffairs/careerinfo.htm>

For information on careers in microbiology, contact:

► American Society for Microbiology, Office of Education and Training—Career Information, 1325 Massachusetts Ave. NW., Washington, DC 20005. Internet: <http://www.asmsusa.org>

Information on obtaining a biological or medical scientist position with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

Chemists and Materials Scientists

(O*NET 19-2031.00, 19-2032.00)

Significant Points

- A bachelor's degree in chemistry or a related discipline is the minimum educational requirement; however, many research jobs require a Ph.D.
- Job growth will be concentrated in pharmaceutical companies and in research and testing services firms.
- Strong demand will exist for those with a master's or Ph.D. degree.

Nature of the Work

Everything in the environment, whether naturally occurring or of human design, is composed of chemicals. Chemists and materials scientists search for and use new knowledge about chemicals. Chemical research has led to the discovery and development of new and improved synthetic fibers, paints, adhesives, drugs, cosmetics, electronic components, lubricants, and thousands of other products. Chemists and materials scientists also develop processes that save energy and reduce pollution, such as improved oil refining and petrochemical processing methods. Research on the chemistry of living things spurs advances in medicine, agriculture, food processing, and other fields.

Materials scientists research and study the structures and chemical properties of various materials to develop new products or enhance existing ones. They also determine ways to strengthen or combine materials or develop new materials for use in a variety of products. Materials science encompasses the natural and synthetic materials used in a wide range of products and structures, from airplanes, cars, and bridges to clothing and household goods. Companies whose products are made of metals, ceramics, and rubber employ most material scientists. Other applications of this field include studies of superconducting materials, graphite materials, integrated-circuit chips, and fuel cells. Materials scientists, applying chemistry and physics, study all aspects of these materials. Chemistry plays an increasingly dominant role in materials science, because it provides information about the structure and composition of materials.

Many chemists and materials scientists work in research and development (R&D). In basic research, they investigate properties, composition, and structure of matter and the laws that govern the combination of elements and reactions of substances. In applied R&D, they create new products and processes or improve existing ones, often using knowledge gained from basic research. For example, synthetic rubber and plastics resulted from research on small molecules uniting to form large ones, a process called polymerization. R&D chemists and material scientists use computers and a wide variety of sophisticated laboratory instrumentation for modeling and simulation in their work.

The use of computers to analyze complex data has had the dramatic impact of allowing chemists and materials scientists to practice combinatorial chemistry. This technique makes and tests large quantities of chemical compounds simultaneously in order to find compounds with desired properties. As an integral part of drug and materials discovery, combinatorial chemistry speeds up material designing and research and development, permitting useful compounds to be developed more quickly and inexpensively than was formerly possible. Combinatorial chemistry has allowed chemists to produce thousands of compounds each year and to assist in the completion of sequencing human genes.

Chemists also work in production and quality control in chemical manufacturing plants. They prepare instructions for plant workers that specify ingredients, mixing times, and temperatures for each stage in the process. They also monitor automated processes to ensure proper product yield, and test samples of raw materials or finished products to ensure that they meet industry and government standards, including the regulations governing pollution. Chemists report and document test results and analyze those results in hopes of further improving existing theories or developing new test methods.

Chemists often specialize in a subfield. *Analytical chemists* determine the structure, composition, and nature of substances by examining and identifying the various elements or compounds that make up a substance. They are absolutely crucial to the pharmaceutical industry because pharmaceutical companies need to know the identity of compounds that they hope to turn into drugs. Furthermore, they study the relations and interactions of the parts of compounds and develop analytical techniques. They also identify the presence and concentration of chemical pollutants in air, water, and soil. *Organic chemists* study the chemistry of the vast number of carbon compounds that make up all living things. Organic chemists who synthesize elements or simple compounds to create new compounds or substances that have different properties and applications have developed many commercial products, such as drugs, plastics, and elastomers (elastic substances similar to rubber). *Inorganic chemists* study compounds consisting mainly of elements other than carbon, such as those in electronic components. *Physical and theoretical*

chemists study the physical characteristics of atoms and molecules and the theoretical properties of matter, and investigate how chemical reactions work. Their research may result in new and better energy sources. *Macromolecular chemists* study the behavior of atoms and molecules. *Medicinal chemists* study the structural properties of compounds intended for applications to human medicine. *Materials chemists* study and develop new materials to improve existing products or make new ones. In fact, virtually all chemists are involved in this quest in one way or another. Developments in the field of chemistry that involve life sciences will expand, resulting in more interaction between biologists and chemists. (*Biochemists*, whose work encompasses both biology and chemistry, are discussed in the *Handbook* statement on biological scientists).

Materials scientists also may specialize in specific areas such as ceramics or metals.

Working Conditions

Chemists and materials scientists usually work regular hours in offices and laboratories. Research and development chemists and materials scientists spend much time in laboratories, but also work in offices when they do theoretical research or plan, record, and report on their lab research. Although some laboratories are small, others are large enough to incorporate prototype chemical manufacturing facilities as well as advanced equipment for chemists. In addition to working in a laboratory, materials scientists also work with engineers and processing specialists in industrial manufacturing facilities. After a material is sold, materials scientists often help customers tailor the material to suit their needs. Chemists do some of their work in a chemical plant or outdoors—while gathering water samples to test for pollutants, for example. Some chemists are exposed to health or safety hazards when handling certain chemicals, but there is little risk if proper procedures are followed.

Employment

Chemists and materials scientists held about 92,000 jobs in 2000. Over half of all chemists are employed in manufacturing firms—mostly in the chemical manufacturing industry, which includes firms that produce plastics and synthetic materials, drugs, soaps and cleaners, paints, industrial organic chemicals, and other miscellaneous chemical products. Chemists also work for State and local governments and for Federal agencies. The U.S. Department of Health and Human Services (which includes the Food and Drug Administration, the National Institutes of Health, and the Center for Disease Control) is the major Federal employer of chemists. The Departments of Defense and Agriculture and the Environmental Protection Agency also employ chemists. Other chemists work for research, development, and testing services. In addition, thousands of persons with a background in chemistry and materials science hold teaching positions in high schools and in colleges and universities. (See the two statements on teachers—postsecondary and teachers—preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook*.)

Chemists and materials scientists are employed in all parts of the country, but they are mainly concentrated in large industrial areas.

Training, Other Qualifications, and Advancement

A bachelor's degree in chemistry or a related discipline is usually the minimum educational requirement for entry-level chemist jobs. However, many research jobs require a Ph.D. While some materials scientists hold a degree in materials science, a bachelor's degree in chemistry, physics, or electric engineering also is accepted. For research and development jobs, a Ph.D. in materials science or a related science is often required.



Job growth for chemists will be concentrated in research and testing service firms.

Many colleges and universities offer a bachelor's degree program in chemistry; about 620 are approved by the American Chemical Society (ACS). The number of colleges that offer a degree program in materials science is small, but gradually increasing. Several hundred colleges and universities also offer advanced degree programs in chemistry; around 320 master's programs, and about 190 doctoral programs are ACS-approved.

Students planning careers as chemists and materials scientists should take courses in science and mathematics, and should like working with their hands building scientific apparatus and performing laboratory experiments and computer modeling. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. Interaction among specialists in this field is increasing, especially for chemists in drug development. One type of chemist often relies on the findings of another type of chemist. For example, an organic chemist must understand findings on the identity of compounds prepared by an analytical chemist.

In addition to required courses in analytical, inorganic, organic, and physical chemistry, undergraduate chemistry majors usually study biological sciences, mathematics, and physics. Those interested in the environmental field should also take courses in environmental studies and become familiar with current legislation and regulations. Computer courses are essential, as employers increasingly prefer job applicants who are able to apply computer skills to modeling and simulation tasks and operate computerized laboratory equipment. This is increasingly important as combinatorial chemistry techniques are more widely applied. Scientists with outdated skills or who are unfamiliar with combinatorial chemistry are often retrained by companies in-house.

Because research and development chemists and materials scientists are increasingly expected to work on interdisciplinary teams, some understanding of other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships, fellowships, or co-op programs in industry, also is useful. Some employers of research chemists, particularly in the pharmaceutical industry, prefer to hire individuals with several years of postdoctoral experience.

Graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, depending on their interests and the kind of work they wish to do. For example, those interested in doing drug research in the pharmaceutical industry usually develop a strong background in synthetic organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have more flexibility when job hunting or changing jobs than if they narrowly define their interests. Most employers provide new graduates additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in quality control, perform analytical testing, or assist senior chemists in research and development laboratories. Many employers prefer chemists and materials scientists with a Ph.D. or at least a master's degree to lead basic and applied research. Nonetheless, relevant work experience is an asset. Chemists who hold a Ph.D. and have previous industrial experience may be particularly attractive to employers because such people are more likely to understand the complex regulations that apply to the pharmaceutical industry. Within materials science, a broad background in various sciences is preferred. This broad base may be obtained through degrees in physics, engineering, or chemistry. While many companies prefer hiring Ph.D.'s, many materials scientists have bachelor's and master's degrees. Additionally, both chemists and materials scientists need the ability to apply basic statistical techniques.

Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through 2010. Job growth will be concentrated in drug manufacturing and in research, development, and testing services firms. The chemical industry, the major employer of chemists, should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as for more specialty chemicals designed to address specific problems or applications. To meet these demands, chemical firms will continue to devote money to research and development—through in-house teams or outside contractors—spurring employment growth of chemists. Strong demand is expected for chemists with a master's or Ph.D. degree.

Within the chemical industry, job opportunities are expected to be most plentiful in pharmaceutical and biotechnology firms. Biotechnological research, including studies of human genes, continues to offer possibilities for the development of new drugs and products to combat illnesses and diseases which have previously been unresponsive to treatments derived by traditional chemical processes. Stronger competition among drug companies and an aging population are contributing to the need for innovative and improved drugs discovered through scientific research. Chemical firms that develop and manufacture personal products such as toiletries and cosmetics must continually innovate and develop new and better products to remain competitive. Additionally, as the population grows and becomes better informed, the demand for different or improved grooming products—including vegetable-based products, products with milder formulas, treatments for aging skin, and products that have been developed using more benign chemical processes than in the past—will remain strong, spurring the need for chemists.

In most of the remaining segments of the chemical industry, employment growth is expected to decline as companies downsize and turn to outside contractors to provide specialized services. As a result, research and testing firms will experience healthy growth. To control costs, some chemical companies, including drug manufacturers, are increasingly turning to these firms to perform specialized research and other work formerly done by in-house chemists. Despite downsizing, some job openings will result from the need to replace chemists who retire or otherwise leave the labor force. Quality control will continue to be an important issue in the chemical and other industries that use chemicals in their manufacturing processes. Chemists also will be needed to develop and improve the technologies and processes used to produce chemicals for all purposes, and to monitor and measure air and water pollutants to ensure compliance with local, State, and Federal environmental regulations.

Environmental research will offer many new opportunities for chemists and materials scientists. To satisfy public concerns and to comply with government regulations, the chemical industry will continue to invest billions of dollars each year for technology that reduces pollution and cleans up existing waste sites. Chemists also are needed to find ways to use less energy and to discover new sources of energy.

During periods of economic recession, layoffs of chemists may occur—especially in the industrial chemicals industry. This industry provides many of the raw materials to the auto manufacturing and construction industries, both of which are vulnerable to temporary slowdowns during recessions.

Earnings

Median annual earnings of chemists in 2000 were \$50,080. The middle 50 percent earned between \$37,480 and \$68,240. The lowest 10 percent earned less than \$29,620, and the highest 10 percent earned more than \$88,030. Median annual earnings in the industries employing the largest numbers of chemists in 2000 were:

Federal Government	\$65,950
Drugs	50,820
Research and testing services	41,820

A survey by the American Chemical Society reports that the median salary of all their members with a bachelor's degree was \$55,000 a year in 2000; with a master's degree, \$65,000 ; and with a Ph.D., \$82,200. Median salaries were highest for those working in private industry; those in academia earned the least. According to an ACS survey of recent graduates, inexperienced chemistry graduates with a bachelor's degree earned a median starting salary of \$33,500 in 2000; with a master's degree, \$44,100 ; and with a Ph.D., \$64,500 . Among bachelor's degree graduates, those who had completed internships or had other work experience while in school commanded the highest starting salaries.

In 2001, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government averaged \$70,435 a year.

Related Occupations

The research and analysis conducted by chemists and materials scientists is closely related to work done by agricultural and food scientists, biological and medical scientists, chemical engineers, materials engineers, physicists, and science technicians.

Sources of Additional Information

General information on career opportunities and earnings for chemists is available from:

► American Chemical Society, Education Division, 1155 16th St. NW., Washington, DC 20036. Internet: <http://www.acs.org>

Information on obtaining a position as a chemist with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

For general information on materials science, contact:

► Materials Research Society (MRS), 506 Keystone Dr., Warrendale, PA 15086-7573. Internet: <http://www.mrs.org>

Conservation Scientists and Foresters

(O*NET 19-1031.01, 19-1031.02, 19-1031.03, 19-1032.00)

Significant Points

- Nearly 3 out of 4 work for Federal, State, or local governments.
- A bachelor's degree in forestry, range management, or a related field is the minimum educational requirement.
- Projected average employment growth will stem from continuing emphasis on environmental protection and responsible land management.

Nature of the Work

Forests and range lands supply wood products, livestock forage, minerals, and water; serve as sites for recreational activities; and provide habitats for wildlife. Conservation scientists and foresters manage, develop, use, and help to protect these and other natural resources.

Foresters manage forested lands for a variety of purposes. Those working in private industry may manage company forestland or procure timber from private landowners. Company forests are usually managed to produce a sustainable supply of wood for company mills. Procurement foresters contact local forest owners and gain permission to take inventory of the type, amount, and location of all standing timber on the property, a process known as timber cruising. Foresters then appraise the timber's worth, negotiate its purchase, and draw up a contract for procurement. Next, they subcontract with loggers or pulpwood cutters for tree removal, aid in road layout, and maintain close contact with the subcontractor's workers and the landowner to ensure that the work meets the landowner's requirements, as well as Federal, State, and local environmental specifications. Forestry consultants often act as agents for the forest owner, performing these duties and negotiating timber sales with industrial procurement foresters.

Throughout the forest management and procurement processes, foresters consider the economics as well as the environmental impact on natural resources. To do this, they determine how best to conserve wildlife habitats, creek beds, water quality, and soil stability and how best to comply with environmental regulations. Foresters must balance the desire to conserve forested ecosystems for future generations with the need to use forest resources for recreational or economic purposes.

Through a process called regeneration, foresters also supervise the planting and growing of new trees. They choose and prepare the site, using controlled burning, bulldozers, or herbicides to clear weeds, brush, and logging debris. They advise on the type, number, and placement of trees to be planted. Foresters then monitor the seedlings to ensure healthy growth and to determine the best time for harvesting. If they detect signs of disease or harmful insects, they consult with forest pest management specialists to decide on the best course of treatment. Foresters who work for Federal and State governments manage public forests and parks and work with private landowners to protect and manage forest land outside of the public domain. They may also design campgrounds and recreation areas.

Foresters use a number of tools to perform their jobs. Clinometers measure the height, diameter tapes measure the diameter, and increment borers and bark gauges measure the growth of trees so that timber volumes can be computed and growth rates estimated. Photogrammetry and remote sensing (aerial photographs and other imagery taken from airplanes and satellites) often are used for mapping large forest areas and for detecting widespread trends of forest and land use. Computers are used extensively, both in the office and in the field, for the storage, retrieval, and analysis of information required to manage the forest land and its resources.

Range managers, also called *range conservationists*, *range ecologists*, or *range scientists*, study, manage, improve, and protect range lands to maximize their use without damaging the environment. Range lands cover about 1 billion acres of the United States, mostly in western States and Alaska. They contain many natural resources, including grass and shrubs for animal grazing, wildlife habitats, water from vast watersheds, recreation facilities, and valuable mineral and energy resources. Range managers help ranchers attain optimum livestock production by determining the number and kind of animals to graze, the grazing system to use, and the best season for grazing. At the same time, however, they maintain soil stability and vegetation for other uses such as wildlife habitats and outdoor recreation. They also plan and implement revegetation of disturbed sites.

Soil conservationists provide technical assistance to farmers, ranchers, forest managers, State and local agencies, and others concerned with the conservation of soil, water, and related natural resources. They develop programs designed to make the most



Conservation scientists and foresters determine how to best conserve wildlife habitats, water quality, and soil stability in order to protect the ecosystem.

productive use of land without damaging it. Soil conservationists visit areas with erosion problems, find the source of the problem, and help landowners and managers develop management practices to combat it.

Foresters and conservation scientists often specialize in one area, such as forest resource management, urban forestry, wood technology, or forest economics.

Working Conditions

Working conditions vary considerably. Although some of the work is solitary, foresters and conservation scientists also deal regularly with landowners, loggers, forestry technicians and aides, farmers, ranchers, government officials, special interest groups, and the public in general. Some foresters and conservation scientists work regular hours in offices or labs. Others may split their time between field work and office work, while independent consultants and especially new, less experienced workers spend the majority of their time outdoors overseeing or participating in hands-on work.

The work can be physically demanding. Some foresters and conservation scientists work outdoors in all types of weather, sometimes in isolated areas. Other foresters may need to walk long distances through densely wooded land to carry out their work. Foresters also may work long hours fighting fires. Conservation scientists often are called in to prevent erosion after a forest fire, and they provide emergency help after floods, mudslides, and tropical storms.

Employment

Conservation scientists and foresters held about 29,000 jobs in 2000. Nearly 4 out of 10 workers were employed by the Federal Government, many in the U.S. Department of Agriculture (USDA). Foresters were concentrated in the USDA's Forest Service; soil conservationists in the USDA's Natural Resource Conservation Service. Most range managers worked in the Department of the Interior's Bureau of Land Management, the USDA's Natural Resource Conservation Service or Forest Service. About 1 out of 4 conservation scientists and foresters worked for State governments, and nearly 1 out of 10 worked for local governments. The remainder worked in private industry, mainly in research and testing services, the forestry industry, and logging and lumber companies and sawmills. Some were self-employed as consultants for private landowners, Federal and State governments, and forestry-related businesses.

Although conservation scientists and foresters work in every State, employment of foresters is concentrated in the western and southeastern States, where many national and private forests and parks, and most of the lumber and pulpwood-producing forests, are located. Range managers work almost entirely in the western States, where most of the rangeland is located. Soil conservationists, on the other hand, are employed in almost every county in the country.

Training, Other Qualifications, and Advancement

A bachelor's degree in forestry is the minimum educational requirement for professional careers in forestry. In the Federal Government, a combination of experience and appropriate education occasionally may substitute for a 4-year forestry degree, but job competition makes this difficult.

Sixteen States have mandatory licensing or voluntary registration requirements that a forester must meet in order to acquire the title "professional forester" and practice forestry in the State. Licensing or registration requirements vary by State, but usually entail completing a 4-year degree in forestry and a minimum period of training, and passing an exam.

Foresters who wish to perform specialized research or teach should have an advanced degree, preferably a Ph.D.

Most land-grant colleges and universities offer bachelor's or higher degrees in forestry; about 100 of these programs are accredited by the Society of American Foresters. Curriculums stress science, mathematics, communications skills, and computer science, as well as technical forestry subjects. Courses in forest economics and business administration supplement the student's scientific and technical knowledge. Forestry curriculums increasingly include courses on best management practices, wetland analysis, water and soil quality, and wildlife conservation, in response to the growing focus on protecting forested lands during timber harvesting operations. Prospective foresters should have a strong grasp of policy issues and of increasingly numerous and complex environmental regulations, which affect many forestry-related activities. Many colleges require students to complete a field session either in a camp operated by the college or in a cooperative work-study program with a Federal or State agency or private industry. All schools encourage students to take summer jobs that provide experience in forestry or conservation work.

A bachelor's degree in range management or range science is the usual minimum educational requirement for range managers; graduate degrees usually are required for teaching and research positions. In 2000, about 40 colleges and universities offered degrees in range management or range science or in a closely related discipline with a range management or range science option. A number of other schools offered some courses in range management or range science. Specialized range management courses combine plant, animal, and soil sciences with principles of ecology and resource management. Desirable electives include economics, forestry, hydrology, agronomy, wildlife, animal husbandry, computer science, and recreation.

Very few colleges and universities offer degrees in soil conservation. Most soil conservationists have degrees in environmental studies, agronomy, general agriculture, hydrology, or crop or soil science; a few have degrees in related fields such as wildlife biology, forestry, and range management. Programs of study usually include 30 semester hours in natural resources or agriculture, including at least 3 hours in soil science.

In addition to meeting the demands of forestry and conservation research and analysis, foresters and conservation scientists generally must enjoy working outdoors, be physically hardy, and be willing to move to where the jobs are. They also must work well with people and have good communications skills.

Recent forestry and range management graduates usually work under the supervision of experienced foresters or range managers. After gaining experience, they may advance to more responsible positions. In the Federal Government, most entry-level foresters work in forest resource management. An experienced Federal forester may supervise a ranger district, and may advance to forest supervisor, to regional forester, or to a top administrative position in the national headquarters. In private industry, foresters start by learning the practical and administrative aspects of the business and acquiring comprehensive technical training. They are then introduced to contract writing, timber harvesting, and decisionmaking. Some foresters work their way up to top managerial positions within their companies. Foresters in management usually leave the field-work behind, spending more of their time in an office, working with teams to develop management plans and supervising others. After gaining several years of experience, some foresters may become consulting foresters, working alone or with one or several partners. They contract with State or local governments, private landowners, private industry, or other forestry consulting groups.

Soil conservationists usually begin working within one county or conservation district and, with experience, may advance to the area, State, regional, or national level. Also, soil conservationists can transfer to related occupations such as farm or ranch management advisor or land appraiser.

Job Outlook

Employment of conservation scientists and foresters is expected to grow more slowly than the average for all occupations through 2010. Growth should be strongest in State and local governments and in research and testing services, where demand will be spurred by a continuing emphasis on environmental protection and responsible land management. Job opportunities are expected to be best for soil conservationists and other conservation scientists as government regulations, such as those regarding the management of stormwater and coastlines, have created demand for persons knowledgeable about runoff and erosion on farms and in cities and suburbs. Soil and water quality experts also will be needed as States attempt to improve water quality by preventing pollution by agricultural producers and industrial plants.

Fewer opportunities for conservation scientists and foresters are expected in the Federal Government, partly due to budgetary constraints. Also, Federal land management agencies, such as the Forest Service, have de-emphasized their timber programs and increasingly focused on wildlife, recreation, and sustaining ecosystems, thereby increasing demand for other life and social scientists relative to foresters. However, a large number of foresters are expected to retire or leave the Government for other reasons, resulting in many job openings between 2000 and 2010. In addition, a small number of new jobs will result from the need for range and soil conservationists to provide technical assistance to owners of grazing land through the Natural Resource Conservation Service.

Reductions in timber harvesting on public lands, most of which are located in the Northwest and California, also will dampen job growth for private industry foresters in these regions. Opportunities will be better for foresters in the Southeast, where much forested land is privately owned. Rising demand for timber on private lands will increase the need for forest management plans that maximize production while sustaining the ecosystem for future growth. Salaried foresters working for private industry—such as paper companies, sawmills, and pulp wood mills—and consulting foresters will be needed to provide technical assistance and management plans to landowners.

Research and testing firms have increased their hiring of conservation scientists and foresters in recent years in response to demand for professionals to prepare environmental impact statements and erosion and sediment control plans, monitor water quality near logging sites, and advise on tree harvesting practices required by Federal, State, or local regulations. Hiring in these firms should continue during the 2000-10 period, though at a slower rate than over the last 10 years.

Earnings

Median annual earnings of conservation scientists in 2000 were \$47,140. The middle 50 percent earned between \$37,610 and \$56,040. The lowest 10 percent earned less than \$30,240, and the highest 10 percent earned more than \$68,300.

Median annual earnings of foresters in 2000 were \$43,640. The middle 50 percent earned between \$34,760 and \$53,740. The lowest 10 percent earned less than \$27,330, and the highest 10 percent earned more than \$65,960.

In 2001, most bachelor's degree graduates entering the Federal Government as foresters, range managers, or soil conservationists started at \$23,776 or \$30,035, depending on academic achievement. Those with a master's degree could start at \$30,035 or \$42,783. Holders of doctorates could start at \$52,162 or, in research positions, at \$61,451. Beginning salaries were slightly higher in selected areas where the prevailing local pay level was higher. In 2001, the average Federal salary for foresters in nonsupervisory, supervisory, and managerial positions was \$55,006; for soil conservationists, \$53,591; for rangeland managers, \$50,715, and for forest products technologists, \$71,572. According to the National Association of Colleges and Employers, graduates with a bachelor's degree in conservation and renewable natural resources received an average starting salary offer of \$28,571 in 2001.

In private industry, starting salaries for students with a bachelor's degree were comparable with starting salaries in the Federal Government, but starting salaries in State and local governments were usually lower.

Conservation scientists and foresters who work for Federal, State, and local governments and large private firms generally receive more generous benefits than do those working for smaller firms.

Related Occupations

Conservation scientists and foresters manage, develop, and protect natural resources. Other workers with similar responsibilities include agricultural engineers; environmental engineers; agricultural and food scientists; biological scientists; environmental scientists and geoscientists; and farmers, ranchers, and agricultural managers.

Sources of Additional Information

For information about the forestry profession and lists of schools offering education in forestry, send a self-addressed, stamped business envelope to:

► Society of American Foresters, 5400 Grosvenor Lane, Bethesda, MD 20814. Internet: <http://www.safnet.org>

For information about career opportunities in forestry in the Federal Government, contact:

► Chief, U.S. Forest Service, U.S. Department of Agriculture, P.O. Box 96090, Washington, DC 20090-6090. Internet: <http://www.fs.fed.us>

Information about a career as a range manager, as well as a list of schools offering training, is available from:

► Society for Range Management, 445 Union Blvd., Suite 230, Lakewood, CO 80228-1259. Internet: <http://srm.org>

Drafters

(O*NET 17-3011.01, 17-3011.02, 17-3012.01, 17-3012.02, 17-3013.00)

Significant Points

- The type and quality of postsecondary drafting programs vary considerably; prospective students should be careful in selecting a program.
- Opportunities should be best for individuals who have at least 2 years of postsecondary training in drafting and considerable skill and experience using computer-aided drafting (CAD) systems.
- Demand for particular drafting specializations varies geographically, depending on the needs of local industry.

Nature of the Work

Drafters prepare technical drawings and plans used by production and construction workers to build everything from manufactured products, such as toys, toasters, industrial machinery, or spacecraft, to structures, such as houses, office buildings, or oil and gas pipelines. Their drawings provide visual guidelines, showing the technical details of the products and structures and specifying dimensions, materials to be used, and procedures and processes to be followed. Drafters fill in technical details, using drawings, rough sketches, specifications, codes, and calculations previously made by engineers, surveyors, architects, or scientists. For example, they use their knowledge of standardized building techniques to draw in the details of a structure. Some drafters use their knowledge of engineering and manufacturing theory and standards to draw the parts of a machine in order to determine design elements, such as the number and kind of fasteners needed to assemble it. They use technical handbooks, tables, calculators, and computers to do this.

Traditionally, drafters sat at drawing boards and used pencils, pens, compasses, protractors, triangles, and other drafting devices to prepare a drawing manually. Most drafters now use computer-aided drafting (CAD) systems to prepare drawings. Consequently, some drafters are referred to as CAD operators. CAD systems employ computer workstations to create a drawing on a video screen. The drawings are stored electronically so that revisions or duplications can be made easily. These systems also permit drafters to easily and quickly prepare variations of a design. Although drafters use CAD extensively, it is only a tool. Persons who produce technical drawings using CAD still function as drafters, and need the knowledge of traditional drafters—relating to drafting skills and standards—in addition to CAD skills. Despite the near-universal use of CAD systems, manual drafting still is used in certain applications.

Drafting work has many specialties, and titles may denote a particular discipline of design or drafting. *Aeronautical drafters* prepare engineering drawings detailing plans and specifications used for the manufacture of aircraft, missiles, and related parts.

Architectural drafters draw architectural and structural features of buildings and other structures. They may specialize by the type of structure, such as residential or commercial, or by the kind of material used, such as reinforced concrete, masonry, steel, or timber.

Civil drafters prepare drawings and topographical and relief maps used in major construction or civil engineering projects, such as highways, bridges, pipelines, flood control projects, and water and sewage systems.



Drafters use computer-aided drafting systems to prepare drawings.

Electrical drafters prepare wiring and layout diagrams used by workers who erect, install, and repair electrical equipment and wiring in communication centers, powerplants, electrical distribution systems, and buildings.

Electronic drafters draw wiring diagrams, circuitboard assembly diagrams, schematics, and layout drawings used in the manufacture, installation, and repair of electronic devices and components.

Mechanical drafters prepare detail and assembly drawings of a wide variety of machinery and mechanical devices, indicating dimensions, fastening methods, and other requirements.

Process piping or pipeline drafters prepare drawings used for layout, construction, and operation of oil and gas fields, refineries, chemical plants, and process piping systems.

Working Conditions

Drafters usually work in comfortable offices furnished to accommodate their tasks. They may sit at adjustable drawing boards or drafting tables when doing manual drawings, although most drafters work at computer terminals much of the time. Because they spend long periods in front of computer terminals doing detailed work, drafters may be susceptible to eyestrain, back discomfort, and hand and wrist problems.

Employment

Drafters held about 213,000 jobs in 2000. More than 40 percent of drafters worked in engineering and architectural services firms that

design construction projects or do other engineering work on a contract basis for organizations in other industries. Another 29 percent worked in durable goods manufacturing industries, such as machinery, electrical equipment, and fabricated metals. The remainder were mostly employed in the construction; government; transportation, communications, and utilities; and personnel-supply services industries. About 10,000 were self-employed in 2000.

Training, Other Qualifications, and Advancement

Employers prefer applicants who have completed postsecondary school training in drafting, which is offered by technical institutes, community colleges, and some 4-year colleges and universities. Employers are most interested in applicants who have well-developed drafting and mechanical drawing skills; a knowledge of drafting standards, mathematics, science, and engineering technology; and a solid background in computer-aided drafting and design techniques. In addition, communication and problem-solving skills are important.

Individuals planning careers in drafting should take courses in math, science, computer technology, design or computer graphics, and any high school drafting courses available. Mechanical ability and visual aptitude also are important. Prospective drafters should be able to draw three-dimensional objects as well as draw freehand. They also should do detailed work accurately and neatly. Artistic ability is helpful in some specialized fields, as is knowledge of manufacturing and construction methods. In addition, prospective drafters should have good interpersonal skills because they work closely with engineers, surveyors, architects, other professionals, and sometimes customers.

Training and coursework differ somewhat within the drafting specialties. The initial training for each specialty is similar. All incorporate math and communication skills, for example, but coursework relating to the specialty varies. In an electronics drafting program, for example, students learn the ways that electronic components and circuits are depicted in drawings.

Entry-level or junior drafters usually do routine work under close supervision. After gaining experience, intermediate-level drafters progress to more difficult work with less supervision. They may be required to exercise more judgment and perform calculations when preparing and modifying drawings. Drafters may eventually advance to senior drafter, designer, or supervisor. Many employers pay for continuing education and, with appropriate college degrees, drafters may go on to become engineering technicians, engineers, or architects.

Many types of publicly and privately operated schools provide some form of drafting training. The kind and quality of programs vary considerably. Therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs obtained by graduates, type and condition of instructional facilities and equipment, and faculty qualifications.

Technical institutes offer intensive technical training but less general education than junior and community colleges. Certificates or diplomas based on completion of a certain number of course hours may be rewarded. Many technical institutes offer 2-year associate degree programs, which are similar to, or part of, the programs offered by community colleges or State university systems. Other technical institutes are run by private, often for-profit, organizations, sometimes called proprietary schools. Their programs vary considerably in both length and type of courses offered.

Community colleges offer curriculums similar to those in technical institutes but include more courses on theory and liberal arts. Often, there is little or no difference between technical institute and

community college programs. However, courses taken at community colleges are more likely to be accepted for credit at 4-year colleges than are those at technical institutes. After completing a 2-year associate degree program, graduates may obtain jobs as drafters or continue their education in a related field at 4-year colleges. Four-year colleges usually do not offer drafting training, but college courses in engineering, architecture, and mathematics are useful for obtaining a job as a drafter.

Area vocational-technical schools are postsecondary public institutions that serve local students and emphasize training needed by local employers. Many offer introductory drafting instruction. Most require a high school diploma, or its equivalent, for admission.

Technical training obtained in the Armed Forces also can be applied in civilian drafting jobs. Some additional training may be necessary, depending on the technical area or military specialty.

The American Design Drafting Association (ADDA) has established a certification program for drafters. Although drafters usually are not required to be certified by employers, certification demonstrates that the understanding of nationally recognized practices and knowledge standards have been met. Individuals who wish to become certified must pass the Drafter Certification Test, which is administered periodically at ADDA-authorized testsites. Applicants are tested on their knowledge and understanding of basic drafting concepts such as geometric construction, working drawings, and architectural terms and standards.

Job Outlook

Employment of drafters is expected to grow about as fast as the average for all occupations through 2010. Industrial growth and increasingly complex design problems associated with new products and manufacturing processes will increase the demand for drafting services. Further, drafters are beginning to break out of the traditional drafting role and increasingly do work traditionally performed by engineers and architects, thus increasing the need for drafters. However, the greater use of CAD equipment by drafters, as well as by architects and engineers, should limit demand for lesser-skilled drafters. In addition to those created by employment growth, many job openings are expected to arise as drafters move to other occupations or leave the labor force.

Opportunities should be best for individuals who have at least 2 years of postsecondary training in a drafting program that provides strong technical skills, and who have considerable skill and experience using CAD systems. CAD has increased the complexity of drafting applications while enhancing the productivity of drafters. It also has enhanced the nature of drafting by creating more possibilities for design and drafting. As technology continues to advance, employers will look for drafters with a strong background in fundamental drafting principles, a higher level of technical sophistication, and an ability to apply this knowledge to a broader range of responsibilities.

Demand for particular drafting specialties varies throughout the country because employment usually is contingent upon the needs of local industry. Employment of drafters remains highly concentrated in industries that are sensitive to cyclical changes in the economy, such as engineering and architectural services and durable-goods manufacturing. During recessions, drafters may be laid off. However, a growing number of drafters should continue to be employed on a temporary or contract basis, as more companies turn to the personnel-supply services industry to meet their changing needs.

Earnings

Earnings for drafters vary by specialty and level of responsibility. Median hourly earnings of architectural and civil drafters were

\$16.93 in 2000. The middle 50 percent earned between \$13.79 and \$20.86. The lowest 10 percent earned less than \$11.18, and the highest 10 percent earned more than \$26.13. Median hourly earnings of architectural and civil drafters in engineering and architectural services in 2000 were \$16.75.

Median hourly earnings of electrical and electronics drafters were \$18.37 in 2000. The middle 50 percent earned between \$14.19 and \$23.76. The lowest 10 percent earned less than \$11.30, and the highest 10 percent earned more than \$29.46. In engineering and architectural services, the average hourly earnings for electrical and electronics drafters were \$17.30.

Median hourly earnings of mechanical drafters were \$18.19 in 2000. The middle 50 percent earned between \$14.43 and \$23.20. The lowest 10 percent earned less than \$11.70, and the highest 10 percent earned more than \$28.69. The average hourly earnings for mechanical drafters in engineering and architectural services were \$16.98.

Related Occupations

Other workers who prepare or analyze detailed drawings and make precise calculations and measurements include architects, except landscape and naval; landscape architects; designers; engineers; engineering technicians; science technicians; and surveyors, cartographers, photogrammetrists, and surveying technicians.

Sources of Additional Information

Information on schools offering programs in drafting and related fields is available from:

► Accrediting Commission of Career Schools and Colleges of Technology, 2101 Wilson Blvd., Suite 302, Arlington, VA 22201. Internet: <http://www.accset.org>

Information about certification is available from:

► American Design Drafting Association, P.O. Box 11937, Columbia, SC 29211. Internet: <http://www.adda.org>

Engineering Technicians

(O*NET 17-3021.00, 17-3022.00, 17-3023.01, 17-3023.02, 17-3023.03, 17-3024.00, 17-3025.00, 17-3026.00, 17-3027.00)

Significant Points

- Electrical and electronic engineering technicians make up about 45 percent of all engineering technicians.
- Because the type and quality of training programs vary considerably, prospective students should carefully investigate training programs before enrolling.
- Opportunities will be best for individuals with an associate degree or extensive job training in engineering technology.

Nature of the Work

Engineering technicians use the principles and theories of science, engineering, and mathematics to solve technical problems in research and development, manufacturing, sales, construction, inspection, and maintenance. Their work is more limited in scope and more practically oriented than that of scientists and engineers. Many engineering technicians assist engineers and scientists, especially in research and development. Others work in quality control—inspecting products and processes, conducting tests, or collecting data. In manufacturing, they may assist in product design, development, or production.

Although many workers who repair or maintain various types of electrical, electronic, or mechanical equipment often are called technicians, these workers are covered in the *Handbook* section on installation, maintenance, and repair occupations.

Engineering technicians who work in research and development build or set up equipment, prepare and conduct experiments, collect data, calculate or record the results, and help engineers or scientists in other ways, such as making prototype versions of newly designed equipment. They also assist in design work, often using computer-aided design equipment.

Most engineering technicians specialize in certain areas, learning skills and working in the same disciplines as engineers. Occupational titles, therefore, tend to follow the same structure as those of engineers.

Aerospace engineering and operations technicians install, construct, maintain, and test systems used to test, launch, or track aircraft and space vehicles. They may calibrate test equipment and determine the cause of equipment malfunctions. Using computer and communications systems, aerospace engineering and operations technicians often record and interpret test data.

Chemical engineering technicians usually are employed in industries producing pharmaceuticals, chemicals, and petroleum products, among others. They work in laboratories as well as processing plants. They help develop new chemical products and processes, test processing equipment and instrumentation, gather data, and monitor quality.

Civil engineering technicians help civil engineers plan and build highways, buildings, bridges, dams, wastewater treatment systems, and other structures, and perform related surveys and studies. Some estimate construction costs and specify materials to be used, and some may even prepare drawings or perform land-surveying duties. Others may set up and monitor instruments used to study traffic conditions. (Separate statements on cost estimators; drafters; and surveyors, cartographers, photogrammetrists, and surveying technicians can be found elsewhere in the *Handbook*.)

Electrical and electronics engineering technicians help design, develop, test, and manufacture electrical and electronic equipment such as communication equipment, radar, industrial and medical measuring or control devices, navigational equipment, and computers. They may work in product evaluation and testing, using measuring and diagnostic devices to adjust, test, and repair equipment. (Workers who only repair electrical and electronic equipment are discussed in the statement on electrical and electronics installers and repairers found elsewhere in the *Handbook*. Many of these repairers often are referred to as electronics technicians.)

Electrical and electronic engineering technology is also applied to a wide variety of systems such as communications and process controls. *Electromechanical engineering technicians* combine fundamental principles of mechanical engineering technology with knowledge of electrical and electronic circuits to design, develop, test, and manufacture electrical and computer-controlled mechanical systems.

Environmental engineering technicians work closely with environmental engineers and scientists in developing methods and devices used in the prevention, control, or correction of environmental hazards. They inspect and maintain equipment affecting air pollution and recycling. Some inspect water and wastewater treatment systems to ensure that pollution control requirements are met.

Industrial engineering technicians study the efficient use of personnel, materials, and machines in factories, stores, repair shops, and offices. They prepare layouts of machinery and equipment, plan the flow of work, make statistical studies, and analyze production costs.



Some engineering technicians help engineers by setting up equipment and conducting experiments.

Mechanical engineering technicians help engineers design, develop, test, and manufacture industrial machinery, consumer products, and other equipment. They may assist in product tests—by setting up instrumentation for auto crash tests, for example. They may make sketches and rough layouts, record data, make computations, analyze results, and write reports. When planning production, mechanical engineering technicians prepare layouts and drawings of the assembly process and of parts to be manufactured. They estimate labor costs, equipment life, and plant space. Some test and inspect machines and equipment in manufacturing departments or work with engineers to eliminate production problems.

Working Conditions

Most engineering technicians work at least 40 hours a week in laboratories, offices, or manufacturing or industrial plants, or on construction sites. Some may be exposed to hazards from equipment, chemicals, or toxic materials.

Employment

Engineering technicians held about 519,000 jobs in 2000. About 233,000 of these were electrical and electronics engineering technicians. About 35 percent of all engineering technicians worked in durable goods manufacturing, mainly in the electrical and electronic equipment, industrial machinery and equipment, instruments and related products, and transportation equipment industries. Another 26 percent worked in service industries, mostly in engineering or business services companies that do engineering work on contract for government, manufacturing firms, or other organizations.

In 2000, the Federal Government employed about 23,000 engineering technicians. The major employer was the Department of Defense, followed by the Departments of Transportation, Agriculture, and Interior, the Tennessee Valley Authority, and the National Aeronautics and Space Administration. State governments employed about 22,000, and local governments, about 21,000.

Training, Other Qualifications, and Advancement

Although it may be possible to qualify for a few engineering technician jobs without formal training, most employers prefer to hire someone with at least a 2-year associate degree in engineering technology. Training is available at technical institutes, community

colleges, extension divisions of colleges and universities, public and private vocational-technical schools, and the Armed Forces. Persons with college courses in science, engineering, and mathematics may qualify for some positions but may need additional specialized training and experience. Although employers usually do not require engineering technicians to be certified, such certification may provide jobseekers a competitive advantage.

Prospective engineering technicians should take as many high school science and math courses as possible to prepare for postsecondary programs in engineering technology. Most 2-year associate degree programs accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC/ABET) require, at a minimum, college algebra and trigonometry, and one or two basic science courses. Depending on the specialty, more math or science may be required.

The type of technical courses required also depends on the specialty. For example, prospective mechanical engineering technicians may take courses in fluid mechanics, thermodynamics, and mechanical design; electrical engineering technicians may take classes in electric circuits, microprocessors, and digital electronics; and those preparing to work in environmental engineering technology need courses in environmental regulations and safe handling of hazardous materials.

Because many engineering technicians may assist in design work, creativity is desirable. Good communication skills and the ability to work well with others also is important because these workers often are part of a team of engineers and other technicians.

Engineering technicians usually begin by performing routine duties under the close supervision of an experienced technician, technologist, engineer, or scientist. As they gain experience, they are given more difficult assignments with only general supervision. Some engineering technicians eventually become supervisors.

Many publicly and privately operated schools provide technical training; the type and quality of programs vary considerably. Therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs obtained by graduates, instructional facilities and equipment, and faculty qualifications. Graduates of ABET-accredited programs usually are recognized to have achieved an acceptable level of competence in the mathematics, science, and technical courses required for this occupation.

Technical institutes offer intensive technical training through application and practice, but less theory and general education than community colleges. Many offer 2-year associate degree programs, and are similar to or part of a community college or State university system. Other technical institutes are run by private, often for-profit, organizations, sometimes called proprietary schools. Their programs vary considerably in length and types of courses offered, although some are 2-year associate degree programs.

Community colleges offer curriculums that are similar to those in technical institutes, but that may include more theory and liberal arts. Often there may be little or no difference between technical institute and community college programs, as both offer associate degrees. After completing the 2-year program, some graduates get jobs as engineering technicians, while others continue their education at 4-year colleges. However, there is a difference between an associate degree in pre-engineering and one in engineering technology. Students who enroll in a 2-year pre-engineering program may find it very difficult to find work as an engineering technician should they decide not to enter a 4-year engineering program, because pre-engineering programs usually focus less on hands-on applications and more on academic

preparatory work. Conversely, graduates of 2-year engineering technology programs may not receive credit for many of the courses they have taken if they choose to transfer to a 4-year engineering program. Colleges with these 4-year programs usually do not offer engineering technician training, but college courses in science, engineering, and mathematics are useful for obtaining a job as an engineering technician. Many 4-year colleges offer bachelor's degrees in engineering technology, but graduates of these programs often are hired to work as technologists or applied engineers, not technicians.

Area vocational-technical schools, another source of technical training, include postsecondary public institutions that serve local students and emphasize training needed by local employers. Most require a high school diploma or its equivalent for admission.

Other training in technical areas may be obtained in the Armed Forces. Many military technical training programs are highly regarded by employers. However, skills acquired in military programs are often narrowly focused, so they may not be useful in civilian industry, which often requires broader training. Therefore, some additional training may be needed, depending on the acquired skills and the kind of job.

The National Institute for Certification in Engineering Technologies (NICET) has established a voluntary certification program for engineering technicians. Certification is available at various levels, each level combining a written examination in 1 of more than 30 specialties with a certain amount of job-related experience, a supervisory evaluation, and a recommendation.

Job Outlook

Opportunities will be best for individuals with an associate degree or extensive job training in engineering technology. As technology becomes more sophisticated, employers continue to look for technicians who are skilled in new technology and require a minimum of additional job training. An increase in the number of jobs affecting public health and safety should create job opportunities for certified engineering technicians.

Overall employment of engineering technicians is expected to increase about as fast as the average for all occupations through 2010. As production of technical products continues to grow, competitive pressures will force companies to improve and update manufacturing facilities and product designs more rapidly than in the past. However, the growing availability and use of advanced technologies, such as computer-aided design and drafting and computer simulation, will continue to increase productivity and limit job growth. In addition to growth, many job openings will stem from the need to replace technicians who retire or leave the labor force.

Like engineers, employment of engineering technicians is influenced by local and national economic conditions. As a result, the employment outlook varies with industry and specialization. Some types of engineering technicians, such as civil engineering and aerospace engineering and operations technicians, experience greater cyclical fluctuations in employment than do others. Increasing demand for more sophisticated electrical and electronic products, as well as the expansion of these products and systems into all areas of industry and manufacturing processes, will contribute to average growth in the largest specialty—electrical and electronics engineering technicians. At the same time, new specializations will contribute to growth among all other engineering technicians; fire protection engineering, water quality control, and environmental technology are some of many new specialties for which demand is increasing.

Earnings

Median annual earnings of electrical and electronics engineering technicians were \$40,020 in 2000. The middle 50 percent earned between \$31,570 and \$49,680. The lowest 10 percent earned less than \$25,210, and the highest 10 percent earned more than \$58,320. Median annual earnings in the industries employing the largest numbers of electrical and electronics engineering technicians in 2000 are shown below.

Federal Government	\$50,000
Telephone communication	45,640
Engineering and architectural services	40,690
Electrical goods	38,120
Electronic components and accessories	35,500

Median annual earnings of civil engineering technicians were \$35,990 in 2000. The middle 50 percent earned between \$27,810 and \$44,740. The lowest 10 percent earned less than \$21,830, and the highest 10 percent earned more than \$54,770. Median annual earnings in the industries employing the largest numbers of civil engineering technicians in 2000 are shown below.

Local government	\$39,080
Engineering and architectural services	36,670
State government	32,160

In 2000, the average annual salary for aerospace engineering and operations technicians in the aircraft and parts industry was \$53,340, and the average annual salary for environmental engineering technicians in engineering and architectural services was \$29,960. The average annual salary for industrial engineering technicians in computer and data processing services and electric components and accessories was \$73,320 and \$36,300, respectively. In engineering and architectural services, the average annual salary for mechanical engineering technicians was \$40,580.

Related Occupations

Engineering technicians apply scientific and engineering principles usually acquired in postsecondary programs below the baccalaureate level. Similar occupations include science technicians; drafters; surveyors, cartographers, photogrammetrists, and surveying technicians; and broadcast and sound engineering technicians and radio operators.

Sources of Additional Information

For \$3.50, a full package of guidance materials and information (product number SP-01) on a variety of engineering technician and technology careers is available from:

- Junior Engineering Technical Society (JETS), 1420 King St., Suite 405, Alexandria, VA 22314-2794. Free information is available on the JETS Internet site: <http://www.jets.org>

Information on ABET-accredited engineering technology programs is available from:

- Accreditation Board for Engineering and Technology, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202. Internet: <http://www.abet.org>

Information on certification of engineering technicians is available from:

- National Institute for Certification in Engineering Technologies (NICET), 1420 King St., Alexandria, VA 22314-2794. Internet: <http://www.nicet.org>

Engineers

(O*NET 17-2011.00, 17-2021.00, 17-2031.00, 17-2041.00, 17-2051.00, 17-2061.00, 17-2071.00, 17-2072.00, 17-2081.00, 17-2111.01, 17-2111.02, 17-2111.03, 17-2112.00, 17-2121.01, 17-2121.02, 17-2131.00, 17-2141.00, 17-2151.00, 17-2161.00, 17-2171.00, 17-2199.99)

Significant Points

- Overall job opportunities in engineering are expected to be good, but to vary by specialty.
- A bachelor's degree is required for most entry-level jobs.
- Starting salaries are significantly higher than those of college graduates in other fields.
- Continuing education is critical to keep abreast of the latest technology.

Nature of the Work

Engineers apply the theories and principles of science and mathematics to research and develop economical solutions to technical problems. Their work is the link between perceived social needs and commercial applications. Engineers design products, machinery to build those products, factories in which those products are made, and the systems that ensure the quality of the products and efficiency of the workforce and manufacturing process. Engineers design, plan, and supervise the construction of buildings, highways, and transit systems. They develop and implement improved ways to extract, process, and use raw materials, such as petroleum and natural gas. They develop new materials that both improve the performance of products and take advantage of advances in technology. They harness the power of the sun, the Earth, atoms, and electricity for use in supplying the Nation's power needs, and create millions of products using power. They analyze the impact of the products they develop or the systems they design on the environment and people using them. Engineering knowledge is applied to improving many things, including the quality of health care, the safety of food products, and the efficient operation of financial systems.

Engineers consider many factors when developing a new product. For example, in developing an industrial robot, engineers determine precisely what function the robot needs to perform; design and test the robot's components; fit the components together in an integrated plan; and evaluate the design's overall effectiveness, cost, reliability, and safety. This process applies to many different products, such as chemicals, computers, gas turbines, helicopters, and toys.

In addition to design and development, many engineers work in testing, production, or maintenance. These engineers supervise production in factories, determine the causes of breakdowns, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some move into engineering management or into sales. In sales, an engineering background enables them to discuss technical aspects and assist in product planning, installation, and use. (See the statements on engineering and natural sciences managers and sales engineers elsewhere in the *Handbook*.)

Most engineers specialize. More than 25 major specialties are recognized by professional societies, and the major branches have numerous subdivisions. Some examples include structural, environmental, and transportation engineering, which are subdivisions of civil engineering; and ceramic, metallurgical, and polymer engineering, which are subdivisions of materials engineering. Engineers also may specialize in one industry, such as motor vehicles, or in one field of technology, such as turbines or semiconductor materials.

This statement, which contains an overall discussion of engineering, is followed by separate statements on 14 engineering branches: aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering. (Computer software engineers are discussed elsewhere in the *Handbook*.) Some branches of engineering not covered in detail in the Handbook, but for which there are established college programs, include architectural engineering—the design of a building's internal support structure; and marine engineering—the design and installation of ship machinery and propulsion systems.

Engineers in each branch have a base of knowledge and training that can be applied in many fields. Electronics engineers, for example, work in the medical, computer, communications, and missile guidance fields. Because there are many separate problems to solve in a large engineering project, engineers in one field often work closely with specialists in other scientific, engineering, and business occupations.

Engineers use computers to produce and analyze designs; to simulate and test how a machine, structure, or system operates; and to generate specifications for parts. New communications technologies using computers are changing the way engineers work on designs. Engineers can collaborate on designs with other engineers around the country or even abroad, using the Internet or related communications systems. Many engineers also use computers to monitor product quality and control process efficiency. They spend a great deal of time writing reports and consulting with other engineers, as complex projects often require an interdisciplinary team of engineers. Supervisory engineers are responsible for major components or entire projects.

Working Conditions

Most engineers work in office buildings, laboratories, or industrial plants. Others may spend time outdoors at construction sites, mines, and oil and gas exploration and production sites, where they monitor or direct operations or solve onsite problems. Some engineers travel extensively to plants or worksites.

Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job. When this happens, engineers may work longer hours and experience considerable stress.

Employment

In 2000, engineers held 1.5 million jobs. The following tabulation shows the distribution of employment by engineering specialty.

<i>Specialty</i>	<i>Employment</i>	<i>Percent</i>
Total, all engineers	1,465,000	100
Electrical and electronics	288,000	20
Civil	232,000	16
Mechanical	221,000	15
Industrial, including health and safety	198,000	14
Computer hardware	60,000	4
Environmental	52,000	4
Aerospace	50,000	3
Chemical	33,000	2
Materials	33,000	2
Nuclear	14,000	1
Petroleum	9,000	1
Biomedical	7,200	<1
Mining and geological, including mining safety	6,500	<1
Marine engineers and naval architects	5,100	<1
Agricultural	2,400	<1
All other engineers	253,000	17

Almost half of all wage and salary engineering jobs were found in manufacturing industries, such as transportation equipment, electrical and electronic equipment, industrial machinery, and instruments and related products. About 401,000 wage and salary jobs were in services industries, primarily in engineering and architectural services, research and testing services, and business services, where firms designed construction projects or did other engineering work on a contractual basis. Engineers also worked in the construction and transportation, communications and utilities industries.

Federal, State, and local governments employed about 179,000 engineers in 2000. Almost half of these were in the Federal Government, mainly in the Departments of Defense, Transportation, Agriculture, Interior, and Energy, and in the National Aeronautics and Space Administration. Most engineers in State and local government agencies worked in highway and public works departments. In 2000, about 43,000 engineers were self-employed, many as consultants.

Engineers are employed in every State, in small and large cities, and in rural areas. Some branches of engineering are concentrated in particular industries and geographic areas, as discussed later in this chapter.

Training, Other Qualifications, and Advancement

A bachelor's degree in engineering is required for almost all entry-level engineering jobs. College graduates with a degree in a physical science or mathematics occasionally may qualify for some engineering jobs, especially in specialties in high demand. Most engineering degrees are granted in electrical, electronics, mechanical, or civil engineering. However, engineers trained in one branch may work in related branches. For example, many aerospace engineers have training in mechanical engineering. This flexibility allows employers to meet staffing needs in new technologies and specialties in which engineers are in short supply. It also allows engineers to shift to fields with better employment prospects or to those that more closely match their interests.

Most engineering programs involve a concentration of study in an engineering specialty, along with courses in both mathematics and science. Most programs include a design course, sometimes accompanied by a computer or laboratory class or both.

In addition to the standard engineering degree, many colleges offer 2- or 4-year degree programs in engineering technology. These programs, which usually include various hands-on laboratory classes that focus on current issues, prepare students for practical design and production work, rather than for jobs which require more theoretical and scientific knowledge. Graduates of 4-year technology

programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering. Some employers regard technology program graduates as having skills between those of a technician and an engineer.

Graduate training is essential for engineering faculty positions and many research and development programs, but is not required for the majority of entry-level engineering jobs. Many engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education. Many high-level executives in government and industry began their careers as engineers.

About 330 colleges and universities offer bachelor's degree programs in engineering that are accredited by the Accreditation Board for Engineering and Technology (ABET), and about 250 colleges offer accredited bachelor's degree programs in engineering technology. ABET accreditation is based on an examination of an engineering program's student achievement, program improvement, faculty, curricular content, facilities, and institutional commitment. Although most institutions offer programs in the major branches of engineering, only a few offer programs in the smaller specialties. Also, programs of the same title may vary in content. For example, some programs emphasize industrial practices, preparing students for a job in industry, whereas others are more theoretical and are designed to prepare students for graduate work. Therefore, students should investigate curricula and check accreditations carefully before selecting a college.

Admissions requirements for undergraduate engineering schools include a solid background in mathematics (algebra, geometry, trigonometry, and calculus) and sciences (biology, chemistry, and physics), and courses in English, social studies, humanities, and computers. Bachelor's degree programs in engineering typically are designed to last 4 years, but many students find that it takes between 4 and 5 years to complete their studies. In a typical 4-year college curriculum, the first 2 years are spent studying mathematics, basic sciences, introductory engineering, humanities, and social sciences. In the last 2 years, most courses are in engineering, usually with a concentration in one branch. For example, the last 2 years of an aerospace program might include courses in fluid mechanics, heat transfer, applied aerodynamics, analytical mechanics, flight vehicle design, trajectory dynamics, and aerospace propulsion systems. Some programs offer a general engineering curriculum; students then specialize in graduate school or on the job.

Some engineering schools and 2-year colleges have agreements whereby the 2-year college provides the initial engineering education, and the engineering school automatically admits students for their last 2 years. In addition, a few engineering schools have arrangements whereby a student spends 3 years in a liberal arts college studying pre-engineering subjects and 2 years in an engineering school studying core subjects, and then receives a bachelor's degree from each school. Some colleges and universities offer 5-year master's degree programs. Some 5- or even 6-year cooperative plans combine classroom study and practical work, permitting students to gain valuable experience and finance part of their education. All 50 States and the District of Columbia usually require licensure for engineers who offer their services directly to the public. Engineers who are licensed are called Professional Engineers (PE). This licensure generally requires a degree from an ABET-accredited engineering program, 4 years of relevant work experience, and successful completion of a State examination. Recent graduates can start the licensing process by taking the examination in two stages. The initial Fundamentals of Engineering (FE) examination can be taken upon graduation. Engineers who pass this examination commonly are called Engineers in Training (EIT) or Engineer Interns (EI). The EIT certification

usually is valid for 10 years. After acquiring suitable work experience, EITs can take the second examination, the Principles and Practice of Engineering Exam. Several States have imposed mandatory continuing education requirements for relicensure. Most States recognize licensure from other States. Many civil, electrical, mechanical, and chemical engineers are licensed as PEs.

Engineers should be creative, inquisitive, analytical, and detail-oriented. They should be able to work as part of a team and to communicate well, both orally and in writing. Communication abilities are becoming more important because much of their work is becoming more diversified, meaning that engineers interact with specialists in a wide range of fields outside engineering.

Beginning engineering graduates usually work under the supervision of experienced engineers and, in large companies, also may receive formal classroom or seminar-type training. As new engineers gain knowledge and experience, they are assigned more difficult projects with greater independence to develop designs, solve problems, and make decisions. Engineers may advance to become technical specialists or to supervise a staff or team of engineers and technicians. Some may eventually become engineering managers or enter other managerial or sales jobs. (See the statements under management and business and financial operations occupations, and sales and related occupations elsewhere in the *Handbook*.)

Job Outlook

Overall engineering employment is expected to increase more slowly than the average for all occupations. However, overall job opportunities in engineering are expected to be good through 2010 because the number of engineering degrees granted is not expected to increase significantly over the 2000-10 period. Projected employment growth and, thus, job opportunities vary by specialty, ranging from a decline in employment of mining and geological engineers to faster-than-average growth among environmental engineers. Competitive pressures and advancing technology will force companies to improve and update product designs and to optimize their manufacturing processes. Employers will rely on engineers to further increase productivity, as investment in plant and equipment increases to expand output of goods and services. New computer and communications systems have improved the design process, enabling engineers to produce and analyze various product designs much more rapidly than in the past and to collaborate on designs with other engineers throughout the world. Despite these widespread applications, computer technology is not expected to limit employment opportunities. Finally, additional engineers will be needed to improve or build new roads, bridges, water and pollution control systems, and other public facilities.

Many engineering jobs are related to developing technologies used in national defense. Because defense expenditures—particularly expenditures for aircraft, missiles, and other weapons systems—are not expected to return to previously high levels, job outlook may not be as favorable for engineers working in defense-related fields although defense expenditures are expected to increase.

The number of bachelor's degrees awarded in engineering began declining in 1987 and has continued to stay at about the same level through much of the 1990s. The total number of graduates from engineering programs is not expected to increase significantly over the projection period.

Although only a relatively small proportion of engineers leaves the profession each year, many job openings will arise from replacement needs. A greater proportion of replacement openings is created by engineers who transfer to management, sales, or other professional occupations than by those who leave the labor force.

Most industries are less likely to lay off engineers than other workers. Many engineers work on long-term research and development projects or in other activities that continue even during

economic slowdowns. In industries such as electronics and aerospace, however, large cutbacks in defense expenditures and government research and development funds, as well as the trend toward contracting out engineering work to engineering services firms, have resulted in significant layoffs for engineers.

It is important for engineers, like those working in other technical occupations, to continue their education throughout their careers because much of their value to their employer depends on their knowledge of the latest technology. Although the pace of technological change varies by engineering specialty and industry, advances in technology have significantly affected every engineering discipline. Engineers in high-technology areas, such as advanced electronics or information technology, may find that technical knowledge can become obsolete rapidly. Even those who continue their education are vulnerable to layoffs if the particular technology or product in which they have specialized becomes obsolete. By keeping current in their field, engineers are able to deliver the best solutions and greatest value to their employers. Engineers who have not kept current in their field may find themselves passed over for promotions or vulnerable to layoffs, should they occur. On the other hand, it often is these high-technology areas that offer the greatest challenges, the most interesting work, and the highest salaries. Therefore, the choice of engineering specialty and employer involves an assessment not only of the potential rewards but also of the risk of technological obsolescence.

Related Occupations

Engineers apply the principles of physical science and mathematics in their work. Other workers who use scientific and mathematical principles include architects, except landscape and naval; engineering and natural sciences managers; computer and information systems managers; mathematicians; drafters; engineering technicians; sales engineers; science technicians; and physical and life scientists, including agricultural and food scientists, biological and medical scientists, conservation scientists and foresters, atmospheric scientists, chemists and materials scientists, environmental scientists and geoscientists, and physicists and astronomers.

Sources of Additional Information

High school students interested in obtaining a full package of guidance materials and information (product number SP-01) on a variety of engineering disciplines should contact the Junior Engineering Technical Society by sending \$3.50 to:

► JETS-Guidance, 1420 King St., Suite 405, Alexandria, VA 22314-2794. Internet: <http://www.jets.org>

High school students interested in obtaining information on ABET-accredited engineering programs should contact:

► The Accreditation Board for Engineering and Technology, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202-4012. Internet: <http://www.abet.org>

Non-licensed engineers and college students interested in obtaining information on Professional Engineer licensure should contact:

► The National Society of Professional Engineers, 1420 King St., Alexandria, VA 22314-2794. Internet: <http://www.nspe.org>
► National Council of Examiners for Engineers and Surveying, P.O. Box 1686, Clemson, SC 29633-1686. Internet: <http://www.ncees.org>

Information on general engineering education and career resources is available from:

► American Society for Engineering Education, 1818 N St. NW., Suite 600, Washington, DC 20036-2479. Internet: <http://www.asee.org>

Information on obtaining an engineering position with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or

call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

Non-high school students and those wanting more detailed information should contact societies representing the individual branches of engineering. Each can provide information about careers in the particular branch. The individual statements that follow also provide other information in detail on aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering.

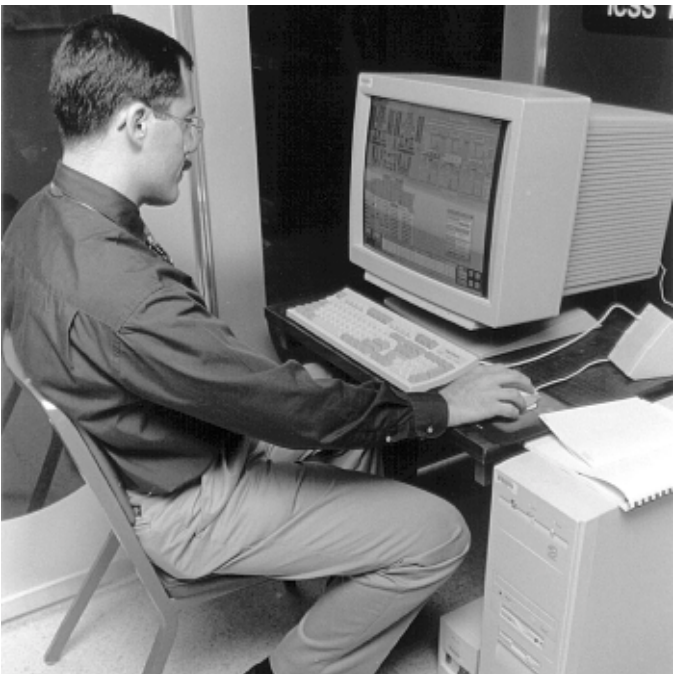
Aerospace Engineers

(O*NET 17-2011.00)

Nature of the Work

Aerospace engineers are responsible for developing extraordinary machines, from airplanes that weigh over a half a million pounds to spacecraft that travel over 17,000 miles an hour. They design, develop, and test aircraft, spacecraft, and missiles and supervise the manufacturing of these products. Aerospace engineers who work with aircraft are considered *aeronautical engineers*, and those working specifically with spacecraft are considered *astronautical engineers*.

Aerospace engineers develop new technologies for use in aviation, defense systems, and space exploration, often specializing in areas such as structural design, guidance, navigation and control, instrumentation and communication, or production methods. They often use Computer-Aided Design (CAD), robotics, and lasers and advanced electronic optics to assist them. They also may specialize in a particular type of aerospace product, such as commercial transports, military fighter jets, helicopters, spacecraft, or missiles and rockets. Aerospace engineers may be experts in aerodynamics,



Aerospace engineers use computer-aided design to develop new technologies.

thermodynamics, celestial mechanics, propulsion, acoustics, or guidance and control systems.

Aerospace engineers typically are employed within the aerospace industry, although their skills are becoming increasingly valuable in other fields. For example, aerospace engineers in the motor vehicles manufacturing industry design vehicles that have lower air resistance, increasing the fuel efficiency of vehicles.

Employment

Aerospace engineers held about 50,000 jobs in 2000. Almost one-half worked in the aircraft and parts and guided missile and space vehicle manufacturing industries. Federal Government agencies, primarily the Department of Defense and the National Aeronautics and Space Administration, provided almost 15 percent of jobs. Engineering and architectural services, research and testing services, and search and navigation equipment firms accounted for most of the remaining jobs.

Job Outlook

Employment of aerospace engineers is expected to grow about as fast as the average for all occupations through 2010. The decline in Defense Department expenditures for military aircraft, missiles, and other aerospace systems has restricted defense-related employment opportunities in recent years. However, an expected increase in defense spending in these areas may result in increased employment of aerospace engineers in defense-related areas during the 2000-10 period. Demand should increase for aerospace engineers to design and produce civilian aircraft, due to the need to accommodate increasing passenger traffic and to replace much of the present fleet with quieter and more fuel-efficient aircraft. Additional opportunities for aerospace engineers will be created with aircraft manufacturers to search for ways to use existing technology for new purposes. Some employment opportunities also will occur in industries not typically associated with aerospace, such as motor vehicles. Most job openings, however, will result from the need to replace aerospace engineers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of aerospace engineers were \$67,930 in 2000. The middle 50 percent earned between \$56,410 and \$82,570. The lowest 10 percent earned less than \$47,700, and the highest 10 percent earned more than \$94,310. Median annual earnings in the industries employing the largest numbers of aerospace engineers in 2000 were:

Federal Government	\$74,170
Search and navigation equipment	71,020
Aircraft and parts	68,230
Guided missiles, space vehicles, and parts	65,830

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in aerospace engineering received starting offers averaging \$46,918 a year, master's degree candidates were offered \$59,955, and Ph.D. candidates were offered \$64,167.

Sources of Additional Information

For further information about aerospace engineers, contact:

- Aerospace Industries Association, 1250 Eye St. NW., Washington, DC 20005. Internet: <http://www.aia-aerospace.org>
- American Institute of Aeronautics and Astronautics, Inc., Suite 500, 1801 Alexander Bell Dr., Reston, VA 20191-4344. Internet: <http://www.aiaa.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Agricultural Engineers

(O*NET 17-2021.00)

Nature of the Work

Agricultural engineers apply knowledge of engineering technology and biological science to agriculture. They design agricultural machinery and equipment and agricultural structures. They develop ways to conserve soil and water and to improve the processing of agricultural products. Agricultural engineers work in research and development, production, sales, or management.

Employment

More than one third of the 2,400 agricultural engineers employed in 2000 worked for engineering and management services, supplying consultant services to farmers and farm-related industries. Others worked in a wide variety of industries, including crops and livestock as well as manufacturing and government.

Job Outlook

Employment of agricultural engineers is expected to increase about as fast as the average for all occupations through 2010. Increasing demand for agricultural products, continued efforts for more efficient agricultural production, and increasing emphasis on the conservation of resources should result in job opportunities for agricultural engineers. However, most openings will be created by the need to replace agricultural engineers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of agricultural engineers were \$55,850 in 2000. The middle 50 percent earned between \$44,220 and \$71,460. The lowest 10 percent earned less than \$33,660, and the highest 10 percent earned more than \$91,600.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in agricultural engineering received starting offers averaging \$46,065 a year and master's degree candidates, on average, were offered \$49,808.



An agricultural engineer sets up tests to measure the amount of nutrients to be applied to a field.

Sources of Additional Information

General information about agricultural engineers can be obtained from:

► American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659. Internet: <http://www.asae.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Biomedical Engineers

(O*NET 17-2031.00)

Nature of the Work

By combining biology and medicine with engineering, biomedical engineers develop devices and procedures that solve medical and health-related problems. Many do research, along with life scientists, chemists, and medical scientists, on the engineering aspects of the biological systems of humans and animals. Biomedical engineers also design devices used in various medical procedures, such as the computers used to analyze blood or the laser systems used in corrective eye surgery. They develop artificial organs, imaging systems such as ultrasound, and devices for automating insulin injections or controlling body functions. Most engineers in this specialty require a sound background in one of the more basic engineering specialties, such as mechanical or electronics engineering, in addition to specialized biomedical training. Some specialties within biomedical engineering include biomaterials, biomechanics, medical imaging, rehabilitation, and orthopedic engineering.

Employment

Biomedical engineers held about 7,200 jobs in 2000. Manufacturing industries employed 30 percent of all biomedical engineers, primarily in the medical instruments and supplies industries. Many others worked for health services. Some also worked on a contract basis for government agencies or as independent consultants.

Job Outlook

Employment of biomedical engineers is expected to increase faster than the average for all occupations through 2010. The aging population and the focus on health issues will increase the demand for



Some specialties within biomedical engineering include biomaterials, biomechanics, medical imaging, rehabilitation, and orthopedic engineering.

better medical devices and systems designed by biomedical engineers. For example, computer-assisted surgery and cellular and tissue engineering are being more heavily researched and are developing rapidly. In addition, the rehabilitation and orthopedic engineering specialties are growing quickly, increasing the need for more biomedical engineers. Along with the demand for more sophisticated medical equipment and procedures is an increased concern for cost efficiency and effectiveness that also will increase the need for biomedical engineers.

Earnings

Median annual earnings of biomedical engineers were \$57,480 in 2000. The middle 50 percent earned between \$45,760 and \$74,120. The lowest 10 percent earned less than \$36,860 and the highest 10 percent earned more than \$90,530.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in biomedical engineering received starting offers averaging \$47,850 a year and master's degree candidates, on average, were offered \$62,600.

Sources of Additional Information

For further information about biomedical engineers, contact:

► Biomedical Engineering Society, 8401 Corporate Dr., Suite 110, Landover, MD 20785-2224. Internet: <http://mecca.org/BME/BMES/society/index.htm>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Chemical Engineers

(O*NET 17-2041.00)

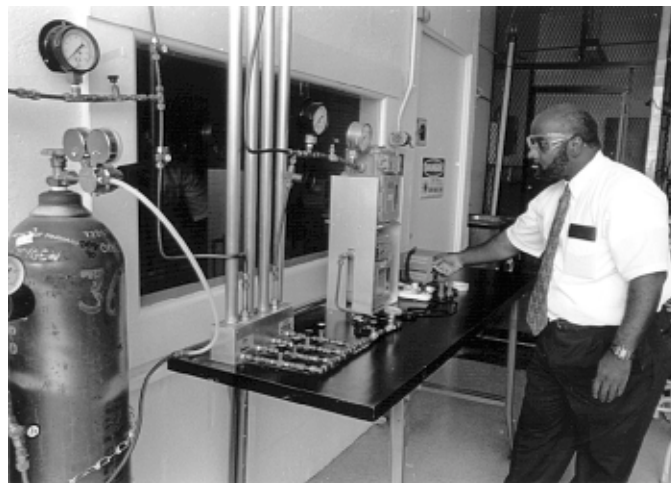
Nature of the Work

Chemical engineers apply the principles of chemistry and engineering to solve problems involving the production or use of chemicals, building a bridge between science and manufacturing. They design equipment and develop processes for large-scale chemical manufacturing, plan and test methods of manufacturing the products and treating the by-products, and supervise production. Chemical engineers also work in a variety of manufacturing industries other than chemical manufacturing, such as those producing electronics, photographic equipment, clothing, and pulp and paper. They also work in the healthcare, biotechnology, and business services industries.

The knowledge and duties of chemical engineers overlap many fields. Chemical engineers apply principles of chemistry, physics, mathematics, and mechanical and electrical engineering. They frequently specialize in a particular operation such as oxidation or polymerization. Others specialize in a particular area, such as pollution control or the production of specific products such as fertilizers and pesticides, automotive plastics, or chlorine bleach. They must be aware of all aspects of chemicals manufacturing and how it affects the environment, the safety of workers, and customers. Because chemical engineers use computer technology to optimize all phases of research and production, they need to understand how to apply computer skills to process analysis, automated control systems, and statistical quality control.

Employment

Chemical engineers held about 33,000 jobs in 2000. Manufacturing industries employed 73 percent of all chemical engineers, primarily in the chemicals, electronics, petroleum refining, paper, and



Among manufacturing industries, specialty chemicals, plastics materials, pharmaceuticals, biotechnology, and electronics may provide the best opportunities for chemical engineers.

related industries. Most others worked for engineering services, research and testing services, or consulting firms that design chemical plants. Some also worked on a contract basis for government agencies or as independent consultants.

Job Outlook

Chemical engineering graduates may face competition for jobs as the number of openings in traditional fields is projected to be lower than the number of graduates. Employment of chemical engineers is projected to grow more slowly than the average for all occupations through 2010. Although overall employment in the chemical manufacturing industry is expected to decline, chemical companies will continue to research and develop new chemicals and more efficient processes to increase output of existing chemicals, resulting in some new jobs for chemical engineers. Among manufacturing industries, specialty chemicals, plastics materials, pharmaceuticals, biotechnology, and electronics may provide the best opportunities. Much of the projected growth in employment of chemical engineers, however, will be in nonmanufacturing industries, especially services industries such as research and testing services.

Earnings

Median annual earnings of chemical engineers were \$65,960 in 2000. The middle 50 percent earned between \$53,440 and \$80,840. The lowest 10 percent earned less than \$45,200, and the highest 10 percent earned more than \$93,430.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in chemical engineering received starting offers averaging \$51,073 a year, master's degree candidates averaged \$57,221, and Ph.D. candidates averaged \$75,521.

Sources of Additional Information

Further information about chemical engineers is available from:

► American Institute of Chemical Engineers, Three Park Ave., New York, NY 10016-5901. Internet: <http://www.aiche.org>
► American Chemical Society, Department of Career Services, 1155 16th St. NW., Washington, DC 20036. Internet: <http://www.acs.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Civil Engineers

(O*NET 17-2051.00)

Nature of the Work

Civil engineers design and supervise the construction of roads, buildings, airports, tunnels, dams, bridges, and water supply and sewage systems. Civil engineering, considered one of the oldest engineering disciplines, encompasses many specialties. The major specialties within civil engineering are structural, water resources, environmental, construction, transportation, and geotechnical engineering.

Many civil engineers hold supervisory or administrative positions, from supervisor of a construction site to city engineer. Others may work in design, construction, research, and teaching.

Employment

Civil engineers held about 232,000 jobs in 2000. A little over half were employed by firms providing engineering consulting services, primarily developing designs for new construction projects. Almost one third of the jobs were in Federal, State, and local government agencies. The construction and manufacturing industries accounted for most of the remaining employment. About 12,000 civil engineers were self-employed, many as consultants.

Civil engineers usually work near major industrial and commercial centers, often at construction sites. Some projects are situated

in remote areas or in foreign countries. In some jobs, civil engineers move from place to place to work on different projects.

Job Outlook

Employment of civil engineers is expected to increase about as fast as the average for all occupations through 2010. Spurred by general population growth and an expanding economy, more civil engineers will be needed to design and construct higher capacity transportation, water supply, pollution control systems, and large buildings and building complexes. They also will be needed to repair or replace existing roads, bridges, and other public structures. There may be additional opportunities within noncivil engineering firms, such as management consulting or computer services firms. In addition to job growth, openings will result from the need to replace civil engineers that transfer to other occupations or leave the labor force.

Because construction and related industries—including those providing design services—employ many civil engineers, employment opportunities will vary by geographic area and may decrease during economic slowdowns, when construction often is curtailed.

Earnings

Median annual earnings of civil engineers were \$55,740 in 2000. The middle 50 percent earned between \$45,150 and \$69,470. The lowest 10 percent earned less than \$37,430, and the highest 10 percent earned more than \$86,000. Median annual earnings in the industries employing the largest numbers of civil engineers in 2000 were:

Federal Government	\$63,530
Heavy construction, except highway	62,010
Local government	56,830
State government	54,630
Engineering and architectural services	54,550

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in civil engineering received starting offers averaging \$40,616 a year, master's degree candidates received an average offer of \$44,080, and Ph.D. candidates were offered \$62,280 as an initial salary.

Sources of Additional Information

Further information about civil engineers can be obtained from:

► American Society of Civil Engineers, 1801 Alexander Bell Dr., Reston, VA 20191-4400. Internet: <http://www.asce.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Computer Hardware Engineers

(O*NET 17-2061.00)

Nature of the Work

Computer hardware engineers research, design, develop, and test computer hardware and supervise its manufacture and installation. Hardware refers to computer chips, circuit boards, computer systems, and related equipment such as keyboards, modems, and printers. (Computer software engineers—often simply called computer engineers—design and develop the software systems that control computers. These workers are covered elsewhere in the *Handbook*.) The work of computer hardware engineers is very similar to that of electronics engineers, but unlike electronics engineers, computer hardware engineers work with computers and computer-related



Civil engineers check on construction sites and monitor progress.



Computer hardware engineers work with circuit boards, computer chips, keyboards, modems, and scanners.

equipment exclusively. (See the statement on electrical and electronics engineers elsewhere in the *Handbook*.) In addition to design and development, computer hardware engineers may supervise the manufacturing and installation of computers and computer-related equipment. The rapid advances in computer technology are largely a result of the research, development, and design efforts of computer hardware engineers. To keep up with technology change, these engineers must continually update their knowledge.

Employment

The number of computer hardware engineers is relatively small compared with the number of other computer-related workers who work with software or computer applications. Computer hardware engineers held about 60,000 jobs in 2000. About 25 percent were employed in computer and data processing services. About 1 out of 10 worked in computer and office equipment manufacturing, but many also are employed in communications industries and engineering consulting firms.

Job Outlook

Computer hardware engineers are expected to have favorable job opportunities. Employment of computer hardware engineers is projected to increase faster than the average for all occupations through 2010, reflecting rapid employment growth in the computer and office equipment industry, which employs the greatest number of computer engineers. Consulting opportunities for computer hardware engineers should grow as businesses need help managing, upgrading, and customizing increasingly complex systems. Growth in embedded systems, a technology that uses computers to control other devices such as appliances or cell phones, also will increase the demand for computer hardware engineers. In addition to job openings arising from employment growth, other vacancies will result from the need to replace workers who move into managerial positions, transfer to other occupations, or leave the labor force.

Earnings

Median annual earnings of computer hardware engineers were \$67,300 in 2000. The middle 50 percent earned between \$52,960 and \$86,280. The lowest 10 percent earned less than \$42,620, and the highest 10 percent earned more than \$107,360. Median annual earnings in the industries employing the largest numbers of computer hardware engineers in 2000 were:

Computer and office equipment	\$75,730
Computer and data processing services	69,490
Electronic components and accessories	67,800
Telephone communication	59,160

Starting salaries for computer engineers with a bachelor's degree can be significantly higher than salaries of bachelor's degree graduates in many other fields. According to the National Association of Colleges and Employers, starting salary offers in 2001 for bachelor's degree candidates in computer engineering averaged \$53,924 a year; master's degree candidates averaged \$58,026; and Ph.D. candidates averaged \$70,140.

Sources of Additional Information

For further information about computer hardware engineers, contact:

► IEEE Computer Society, 1730 Massachusetts Ave. NW., Washington, DC 20036-1992. Internet: <http://www.computer.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Electrical and Electronics Engineers

(O*NET 17-2071.00, 17-2072.00)

Nature of the Work

From geographical information systems that can continuously provide the location of a vehicle to giant electric power generators, electrical and electronics engineers are responsible for a wide range of technologies. Electrical and electronics engineers design, develop, test, and supervise the manufacture of electrical and electronic equipment. Some of this equipment includes power generating, controlling, and transmission devices used by electric utilities; and electric motors, machinery controls, lighting, and wiring in buildings, automobiles, aircraft, radar and navigation systems, and broadcast and communications systems. Many electrical and electronics engineers also work in areas closely related to computers. However, engineers whose work is related exclusively to computer hardware are considered computer hardware engineers, an occupation covered elsewhere in the *Handbook*.

Electrical and electronics engineers specialize in different areas such as power generation, transmission, and distribution; communications; and electrical equipment manufacturing, or a subdivision of these areas—industrial robot control systems or aviation



An electrical engineer working for a consulting firm looks for defective circuits.

electronics, for example. Electrical and electronics engineers design new products, write performance requirements, and develop maintenance schedules. They also test equipment, solve operating problems, and estimate the time and cost of engineering projects.

Employment

Electrical and electronics engineers held about 288,000 jobs in 2000, making their occupation the largest branch of engineering. Most jobs were in engineering and business consulting firms, government agencies, and manufacturers of electrical and electronic and computer and office equipment, industrial machinery, and professional and scientific instruments. Transportation, communications, and utilities firms as well as personnel supply services and computer and data processing services firms accounted for most of the remaining jobs.

California, Texas, New York, and New Jersey—States with many large electronics firms—employ nearly one-third of all electrical and electronics engineers.

Job Outlook

Electrical and electronics engineering graduates should have favorable job opportunities. The number of job openings resulting from employment growth and the need to replace electrical engineers who transfer to other occupations or leave the labor force is expected to be in rough balance with the supply of graduates. Employment of electrical and electronics engineers is expected to grow about as fast as the average for all occupations through 2010.

Projected job growth stems largely from increased demand for electrical and electronic goods, including advanced communications equipment, defense-related electronic equipment, and consumer electronics products. The need for electronics manufacturers to invest heavily in research and development to remain competitive and gain a scientific edge will provide openings for graduates who have learned the latest technologies. Opportunities for electronics engineers in defense-related firms should improve as aircraft and weapons systems are upgraded with improved navigation, control, guidance, and targeting systems. However, job growth is expected to be fastest in services industries—particularly consulting firms that provide electronic engineering expertise.

Continuing education is important for electrical and electronics engineers. Engineers who fail to keep up with the rapid changes in technology risk becoming more susceptible to layoffs or, at a minimum, more likely to be passed over for advancement.

Earnings

Median annual earnings of electrical engineers were \$64,910 in 2000. The middle 50 percent earned between \$51,700 and \$80,600. The lowest 10 percent earned less than \$41,740, and the highest 10 percent earned more than \$94,490. Median annual earnings in the industries employing the largest numbers of electrical engineers in 2000 were:

Computer and office equipment	\$69,700
Measuring and controlling devices	67,570
Search and navigation equipment	67,330
Electronic components and accessories	65,830
Engineering and architectural services	65,040

Median annual earnings of electronics engineers, except computer, were \$64,830 in 2000. The middle 50 percent earned between \$52,430 and \$79,960. The lowest 10 percent earned less than \$43,070, and the highest 10 percent earned more than \$94,330. Median annual earnings in the industries employing the largest numbers of electronics engineers in 2000 were:

Federal Government	\$70,890
Search and navigation equipment	68,930
Electronic components and accessories	63,890
Electrical goods	62,860
Telephone communication	57,710

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in electrical and electronics engineering received starting offers averaging \$51,910 a year; master's degree candidates averaged \$63,812; and Ph.D. candidates averaged \$79,241.

Sources of Additional Information

Information on electrical and electronics engineers is available from:

► Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331. Internet: <http://www.ieee.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Environmental Engineers

(O*NET 17-2081.00)

Nature of the Work

Using the principles of biology and chemistry, environmental engineers develop methods to solve problems related to the environment. They are involved in water and air pollution control, recycling, waste disposal, and public health issues. Environmental engineers conduct hazardous-waste management studies, evaluate the significance of the hazard, offer analysis on treatment and containment, and develop regulations to prevent mishaps. They design municipal sewage and industrial wastewater systems. They analyze scientific data, research controversial projects, and perform quality control checks.

Environmental engineers are concerned with local and worldwide environmental issues. They study and attempt to minimize the effects of acid rain, global warming, automobile emissions, and ozone depletion. They also are involved in the protection of wildlife.

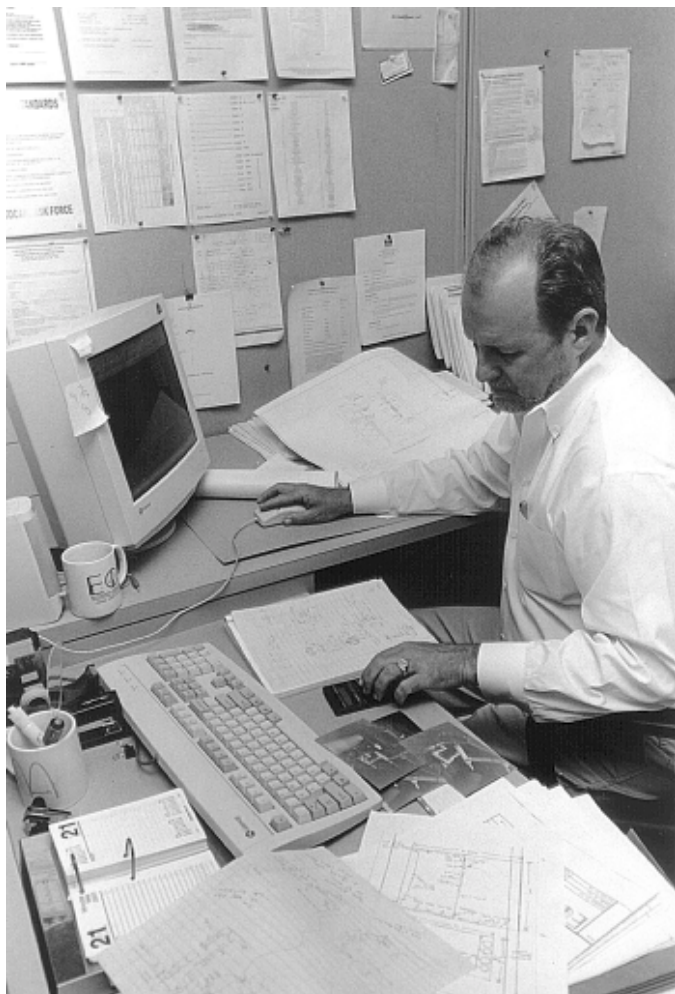
Many environmental engineers work as consultants, helping their clients comply with regulations and clean up hazardous sites, including brownfields, which are abandoned urban or industrial sites that may contain environmental hazards.

Employment

Environmental engineers held about 52,000 jobs in 2000. More than one-third worked in engineering and management services and about 16,000 were employed in Federal, State, and local government agencies. Most of the rest worked in various manufacturing industries.

Job Outlook

Employment of environmental engineers is expected to increase faster than the average for all occupations through 2010. More environmental engineers will be needed to meet environmental regulations and to develop methods of cleaning up existing hazards. A shift in emphasis toward preventing problems rather than controlling those that already exist, as well as increasing public health concerns, also will spur demand for environmental engineers. However, political factors determine the job outlook for environmental engineers more than that for other engineers. Looser environmental regulations would reduce job opportunities; stricter regulations would enhance opportunities.



Although the type of job that environmental engineers have often determines whether they work outdoors, most work in offices the majority of the time.

Even though employment of environmental engineers should be less affected by economic conditions than that of most other types of engineers, a significant economic downturn could reduce the emphasis on environmental protection, reducing employment opportunities. Environmental engineers need to keep abreast of a range of environmental issues to ensure steady employment because their area of focus may change frequently—for example, from hazardous wastesite cleanup to the prevention of water pollution.

Earnings

Median annual earnings of environmental engineers were \$57,780 in 2000. The middle 50 percent earned between \$45,740 and \$71,280. The lowest 10 percent earned less than \$37,210, and the highest 10 percent earned more than \$87,290. Median annual earnings in the industries employing the largest numbers of environmental engineers in 2000 were:

Engineering and architectural services	\$53,580
State government	53,210
Management and public relations	52,110

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in environmental engineering received starting offers averaging \$51,167 a year.

Sources of Additional Information

Further information about environmental engineers can be obtained from:

► American Academy of Environmental Engineers, 130 Holiday Court, Suite 100, Annapolis, MD 21401. Internet: <http://www.enviro-engrs.org>

(See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

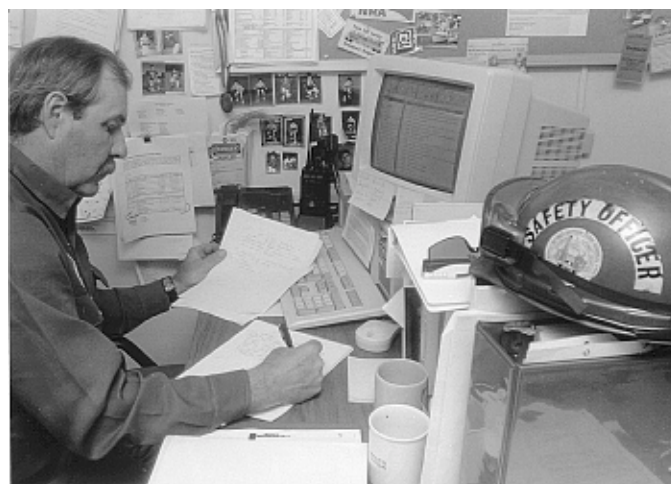
Industrial Engineers, Including Health and Safety

(O*NET 17-2111.01, 17-2111.02, 17-2111.03, 17-2112.00)

Nature of the Work

Industrial engineers determine the most effective ways for an organization to use the basic factors of production—people, machines, materials, information, and energy—to make a product or to provide a service. They are the bridge between management goals and operational performance. They are more concerned with increasing productivity through the management of people, methods of business organization, and technology than are engineers in other specialties, who generally work more with products or processes. Although most industrial engineers work in manufacturing industries, they also work in consulting services, healthcare, and communications.

To solve organizational, production, and related problems most efficiently, industrial engineers carefully study the product and its requirements, use mathematical methods such as operations research to meet those requirements, and design manufacturing and information systems. They develop management control systems to aid in financial planning and cost analysis, design production planning and control systems to coordinate activities and ensure product quality, and design or improve systems for the physical distribution of goods and services. Industrial engineers determine which plant location has the best combination of raw materials availability, transportation facilities, and costs. Industrial engineers use computers for simulations and to control various activities and devices, such as assembly lines and robots. They also develop wage and salary administration systems and job evaluation programs. Many industrial engineers move into management positions because the work is closely related.



Health and safety engineers anticipate and evaluate hazardous conditions and develop hazard control methods.

The work of health and safety engineers is similar to that of industrial engineers in that they are concerned with the entire production process. They promote worksite or product safety and health by applying knowledge of industrial processes, as well as mechanical, chemical, and psychological principles. They must be able to anticipate and evaluate hazardous conditions as well as develop hazard control methods. They also must be familiar with the application of health and safety regulations.

Employment

Industrial engineers, including health and safety, held about 198,000 jobs in 2000. More than 65 percent of these jobs were in manufacturing industries. Because their skills can be used in almost any type of organization, industrial engineers are more widely distributed among manufacturing industries than are other engineers.

Their skills can be readily applied outside manufacturing as well. Some work in engineering and management services, utilities, and business services; others work for government agencies or as independent consultants.

Job Outlook

Despite industrial growth and more complex business operations, overall employment of industrial engineers, including health and safety, is expected to grow more slowly than the average for all occupations through 2010, reflecting greater use of automation in factories and offices. Employment of industrial engineers is expected to grow more slowly than average while health and safety engineers are expected to grow about as fast as average.

Because the main function of industrial and health and safety engineers is to make a higher quality product as efficiently and as safely as possible, their services should be in demand in the manufacturing sector as firms seek to reduce costs and increase productivity. There also is an increased demand for industrial engineers within the financial services sector, as more emphasis is put on information technology. Also, the growing concern for health and safety within work environments should increase the need for health and safety engineers.

Earnings

Median annual earnings of industrial engineers were \$58,580 in 2000. The middle 50 percent earned between \$47,530 and \$71,050. The lowest 10 percent earned less than \$38,140, and the highest 10 percent earned more than \$86,370. Median annual earnings in the manufacturing industries employing the largest numbers of industrial engineers in 2000 were:

Motor vehicles and equipment	\$63,010
Electronic components and accessories	62,560
Computer and office equipment	62,260
Computer and data processing services	60,510
Aircraft and parts	58,290

Median annual earnings of health and safety engineers were \$54,630 in 2000. The middle 50 percent earned between \$44,230 and \$67,500. The lowest 10 percent earned less than \$34,710, and the highest 10 percent earned more than \$82,320. In 2000, the median annual earnings of health and safety engineers in railroads were \$56,970.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in industrial engineering received starting offers averaging about \$48,320 a year; master's degree candidates averaged \$56,265 a year; and Ph.D. candidates were initially offered \$59,800.

Sources of Additional Information

For further information about industrial engineers, contact:

► Institute of Industrial Engineers, Inc., 25 Technology Park/Atlanta, Norcross, GA 30092. Internet: <http://www.iienet.org>

General information about safety engineers is available from:

► American Society of Safety Engineers, 1800 E Oakton St., Des Plaines, IL 60018. Internet: <http://www.asse.org>

Information about certification of safety professionals, including safety engineers, is available from:

! Board of Certified Safety Professionals, 208 Burwash Ave., Savoy, IL 61874. Internet: <http://www.bcsp.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Materials Engineers

(O*NET 17-2131.00)

Nature of the Work

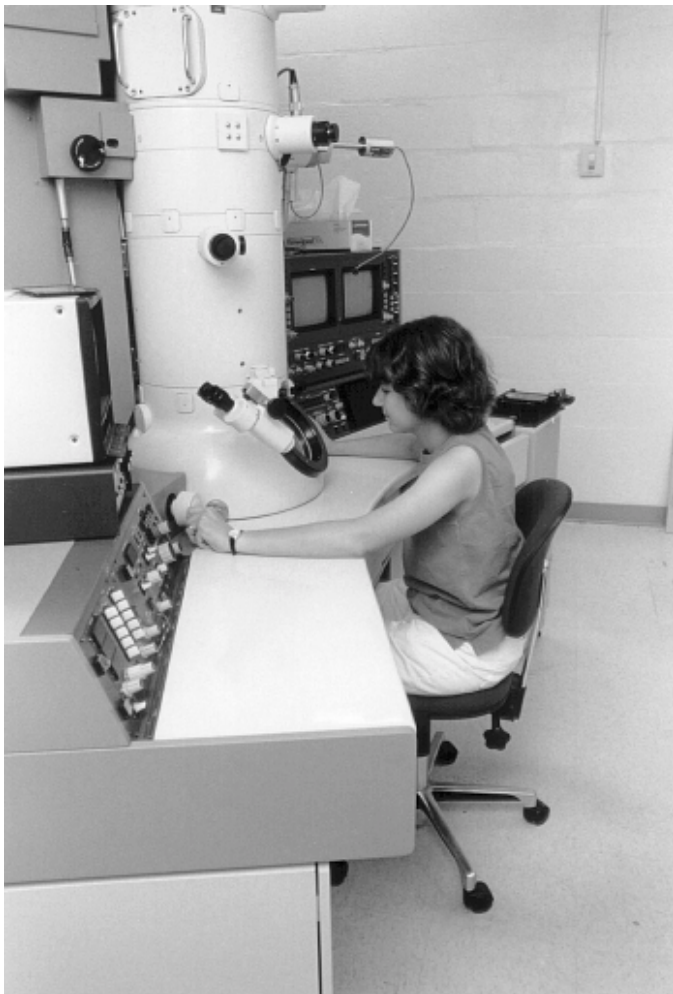
Materials engineers are involved in the extraction, development, processing, and testing of the materials used to create a diversity of products, from computer chips and television screens to golf clubs and snow skis. They work with metals, ceramics, plastics, semiconductors, and combinations of materials called composites to create new materials that meet certain mechanical, electrical, and chemical requirements. They also are involved in selecting materials for new applications.

There are numerous new developments within materials engineering that make it possible to manipulate and use materials in various ways. For example, materials engineers have developed the ability to create and then study materials at an atomic level using advanced processes, electrons, neutrons, or x-rays and to replicate the characteristics of materials and their components with computers.

Materials engineers specializing in metals can be considered *metallurgical engineers*, while those specializing in ceramics can be considered *ceramic engineers*. Most metallurgical engineers work in one of the three main branches of metallurgy—extractive or chemical, physical, and process. Extractive metallurgists are concerned with removing metals from ores and refining and alloying them to obtain useful metal. Physical metallurgists study the nature, structure, and physical properties of metals and their alloys, and relate them to the methods of processing them into final products. Process metallurgists develop and improve metalworking processes such as casting, forging, rolling, and drawing. Ceramic engineers develop ceramic materials and the processes for making ceramic materials into useful products. Ceramics include all non-metallic, inorganic materials that generally require high temperatures in their processing. Ceramic engineers work on products as diverse as glassware, automobile and aircraft engine components, fiber-optic communication lines, tile, and electric insulators.

Employment

Materials engineers held about 33,000 jobs in 2000. Because materials are building blocks for other goods, materials engineers are widely distributed among manufacturing industries. In fact, 84 percent of materials engineers worked in manufacturing industries, primarily metal production and processing, electronic and other electrical equipment, transportation equipment, and industrial machinery and equipment. They also worked in services industries such as engineering and management and research and testing services. Most remaining materials engineers worked for Federal and State governments.



Materials engineers work with metals, ceramics, plastics, semiconductors, and composites to create new materials.

Job Outlook

Employment of materials engineers is expected to grow more slowly than the average for all occupations through 2010. More materials engineers will be needed to develop new materials for electronics and plastics products. However, many of the manufacturing industries in which materials engineers are concentrated—such as primary metals and stone, clay, and glass products—are expected to experience declines in employment, reducing employment opportunities for materials engineers. As firms contract out to meet their materials engineering needs, however, employment growth is expected in many services industries, including research and testing, personnel supply, health, and engineering and architectural services. In addition to growth, job openings will result from the need to replace materials engineers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of materials engineers were \$59,100 in 2000. The middle 50 percent earned between \$47,320 and \$72,900. The lowest 10 percent earned less than \$37,680, and the highest 10 percent earned more than \$87,630.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in materials engineering received starting offers averaging \$49,936 a year.

Sources of Additional Information

For further information about materials engineers, contact:

- Minerals, Metals, & Materials Society, 184 Thorn Hill Rd., Warrendale, PA 15086. Internet: <http://www.tms.org>
- ASM International Foundation, Materials Park, OH 44073-0002. Internet: <http://www.asm-intl.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Mechanical Engineers

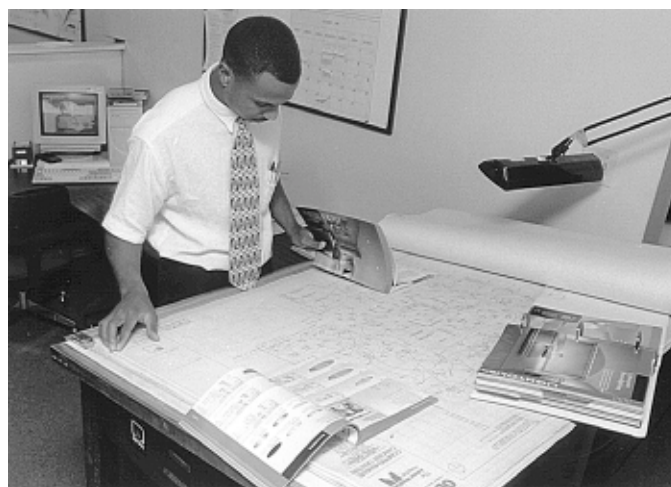
(O*NET 17-2141.00)

Nature of the Work

Mechanical engineers research, develop, design, manufacture, and test tools, engines, machines, and other mechanical devices. They work on power-producing machines such as electric generators, internal combustion engines, and steam and gas turbines. They also develop power-using machines such as refrigeration and air-conditioning equipment, machine tools, material handling systems, elevators and escalators, industrial production equipment, and robots used in manufacturing. Mechanical engineers also design tools needed by other engineers for their work. The field of nanotechnology, which involves the creation of high-performance materials and components by integrating atoms and molecules, is introducing entirely new principles to the design process.

Computers assist mechanical engineers by accurately and efficiently performing computations and by aiding the design process by permitting the modeling and simulation of new designs. Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) are used for design data processing and for developing alternative designs.

Mechanical engineers work in many industries, and their work varies by industry and function. Some specialties include applied mechanics; computer-aided design and manufacturing; energy systems; pressure vessels and piping; and heating, refrigeration, and air-conditioning systems. Mechanical engineering is one of the broadest engineering disciplines. Mechanical engineers may work in production operations in manufacturing or agriculture, maintenance, or technical sales; many are administrators or managers.



A mechanical engineer works on designs for a hospital building.

Employment

Mechanical engineers held about 221,000 jobs in 2000. More than 1 out of 2 jobs were in manufacturing—mostly in machinery, transportation equipment, electrical equipment, instruments, and fabricated metal products industries. Engineering and management services, business services, and the Federal Government provided most of the remaining jobs.

Job Outlook

Employment of mechanical engineers is projected to grow about as fast as the average for all occupations through 2010. Although overall manufacturing employment is expected to grow slowly, employment of mechanical engineers in manufacturing should increase more rapidly as the demand for improved machinery and machine tools grows and industrial machinery and processes become increasingly complex. Also, emerging technologies in information technology, biotechnology, and nanotechnology will create new job opportunities for mechanical engineers.

Employment of mechanical engineers in business and engineering services firms is expected to grow faster than average as other industries in the economy increasingly contract out to these firms to solve engineering problems. In addition to job openings from growth, many openings should result from the need to replace workers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of mechanical engineers were \$58,710 in 2000. The middle 50 percent earned between \$47,600 and \$72,850. The lowest 10 percent earned less than \$38,770, and the highest 10 percent earned more than \$88,610. Median annual earnings in the industries employing the largest numbers of mechanical engineers in 2000 were:

Personnel supply services	\$81,080
Federal government	66,320
Engineering and architectural services	59,800
Motor vehicles and equipment	59,400
Construction and related machinery	54,480

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in mechanical engineering received starting offers averaging \$48,426 a year, master's degree candidates had offers averaging \$55,994, and Ph.D. candidates were initially offered \$72,096.

Sources of Additional Information

Further information about mechanical engineers is available from:

► The American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016. Internet: <http://www.asme.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Mining and Geological Engineers, Including Mining Safety Engineers

(O*NET 17-2151.00)

Nature of the Work

Mining and geological engineers find, extract, and prepare coal, metals, and minerals for use by manufacturing industries and utilities.



Mining engineers work with geologists to discuss plans for further mine excavation.

They design open pit and underground mines, supervise the construction of mine shafts and tunnels in underground operations, and devise methods for transporting minerals to processing plants. Mining engineers are responsible for the safe, economical, and environmentally sound operation of mines. Some mining engineers work with geologists and metallurgical engineers to locate and appraise new ore deposits. Others develop new mining equipment or direct mineral processing operations to separate minerals from the dirt, rock, and other materials with which they are mixed. Mining engineers frequently specialize in the mining of one mineral or metal, such as coal or gold. With increased emphasis on protecting the environment, many mining engineers work to solve problems related to land reclamation and water and air pollution.

Mining safety engineers use their knowledge of mine design and practices to ensure the safety of workers and to comply with State and Federal safety regulations. They inspect walls and roof surfaces, test air samples, and examine mining equipment for compliance with safety practices.

Employment

Mining and geological engineers, including mining safety engineers, held about 6,500 jobs in 2000. While one-half worked in the mining industry, other mining engineers worked in government agencies or engineering consulting firms.

Mining engineers usually are employed at the location of natural deposits, often near small communities, and sometimes outside the United States. Those in research and development, management, consulting, or sales, however, often are located in metropolitan areas.

Job Outlook

Employment of mining and geological engineers, including mining safety engineers, is expected to decline through 2010. Most of the industries in which mining engineers are concentrated—such as coal, metal, and mineral mining, as well as stone, clay, and glass products manufacturing—are expected to experience declines in employment.

Although no job openings are expected to result from employment growth, there should be openings resulting from the need to replace mining engineers who transfer to other occupations or leave the labor force. A large number of mining engineers currently

employed are approaching retirement age. In addition, relatively few schools offer mining engineering programs, and the small number of graduates is not expected to increase.

Mining operations around the world recruit graduates of U.S. mining engineering programs. Consequently, job opportunities may be better worldwide than within the United States. As a result, graduates should be prepared for the possibility of frequent travel or even living abroad.

Earnings

Median annual earnings of mining and geological engineers, including mining safety engineers, were \$60,820 in 2000. The middle 50 percent earned between \$47,320 and \$78,720. The lowest 10 percent earned less than \$36,070, and the highest 10 percent earned more than \$100,050.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in mining engineering received starting offers averaging \$42,507 a year and master's degree candidates, on average, were offered \$54,038.

Sources of Additional Information

For general information about mining engineers, contact:

► The Society for Mining, Metallurgy, and Exploration, Inc., P.O. Box 625002, Littleton, CO 80162-5002. Internet: <http://www.smenet.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Nuclear Engineers

(O*NET 17-2161.00)

Nature of the Work

Nuclear engineers research and develop the processes, instruments, and systems used to derive benefits from nuclear energy and radiation. They design, develop, monitor, and operate nuclear plants used to generate power. They may work on the nuclear fuel cycle—the production, handling, and use of nuclear fuel and the safe disposal of waste produced by nuclear energy—or on fusion energy. Some specialize in the development of nuclear power sources for spacecraft; others find industrial and medical uses for radioactive materials, such as equipment to diagnose and treat medical problems.

Employment

Nuclear engineers held about 14,000 jobs in 2000. About 58 percent were in utilities, 26 percent in engineering consulting firms, and 14 percent in the Federal Government. More than half of all federally employed nuclear engineers were civilian employees of the Navy, and most of the rest worked for the Department of Energy. Most nonfederally employed nuclear engineers worked for public utilities or engineering consulting companies. Some worked for defense manufacturers or manufacturers of nuclear power equipment.

Job Outlook

Good opportunities should exist for nuclear engineers because the small number of nuclear engineering graduates is likely to be in rough balance with the number of job openings. Because this is a small occupation, projected job growth will generate few openings; consequently, most openings will result from the need to replace



Nuclear engineers design, develop, monitor, and operate nuclear plants used to generate power.

nuclear engineers who transfer to other occupations or leave the labor force.

Little or no change in employment of nuclear engineers is expected through 2010. Due to public concerns over the cost and safety of nuclear power, no commercial nuclear power plants are under construction in the United States. Nevertheless, nuclear engineers will be needed to operate existing plants. In addition, nuclear engineers will be needed to work in defense-related areas, to develop nuclear medical technology, and to improve and enforce waste management and safety standards.

Earnings

Median annual earnings of nuclear engineers were \$79,360 in 2000. The middle 50 percent earned between \$67,590 and \$89,310. The lowest 10 percent earned less than \$58,030, and the highest 10 percent earned more than \$105,930. In 2000, the median annual earnings of nuclear engineers in electric services were \$77,890. In the Federal Government, nuclear engineers in supervisory, nonsupervisory, and management positions earned an average of \$71,700 a year in 2001.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in nuclear engineering received starting offers averaging \$49,609 a year and master's degree candidates, on average, were offered \$56,299.

Sources of Additional Information

General information about nuclear engineers is available from:

► American Nuclear Society, 555 North Kensington Ave., LaGrange Park, IL 60525. Internet: <http://www.ans.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Petroleum Engineers

(O*NET 17-2171.00)

Nature of the Work

Petroleum engineers search the world for reservoirs containing oil or natural gas. Once these are discovered, petroleum engineers work with geologists and other specialists to understand the geologic formation and properties of the rock containing the reservoir, determine the drilling methods to be used, and monitor drilling and production operations. They design equipment and processes to achieve the maximum profitable recovery of oil and gas. Petroleum engineers rely heavily on computer models to simulate



Favorable job opportunities are expected for petroleum engineers.

reservoir performance using different recovery techniques. They also use computer models for simulations of the effects of various drilling options.

Because only a small proportion of oil and gas in a reservoir will flow out under natural forces, petroleum engineers develop and use various enhanced recovery methods. These include injecting water, chemicals, gases, or steam into an oil reservoir to force out more of the oil, and computer-controlled drilling or fracturing to connect a larger area of a reservoir to a single well. Because even the best techniques in use today recover only a portion of the oil and gas in a reservoir, petroleum engineers research and develop technology and methods to increase recovery and lower the cost of drilling and production operations.

Employment

Petroleum engineers held about 9,000 jobs in 2000, mostly in oil and gas extraction, petroleum refining, and engineering and architectural services. Employers include major oil companies and hundreds of smaller, independent oil exploration, production, and service companies. Engineering consulting firms and government agencies also employ many petroleum engineers.

Most petroleum engineers work where oil and gas are found. Large numbers are employed in Texas, Louisiana, Oklahoma, and California, including offshore sites. Many American petroleum engineers also work overseas in oil-producing countries.

Job Outlook

Employment of petroleum engineers is expected to decline through 2010 because most of the potential petroleum-producing areas in the United States already have been explored. Even so, favorable opportunities are expected for petroleum engineers because the number of job openings is likely to exceed the relatively small number of graduates. All job openings should result from the need to replace petroleum engineers who transfer to other occupations or leave the labor force.

Also, petroleum engineers work around the world, and many foreign employers seek U.S.-trained petroleum engineers. In fact, the best employment opportunities may be in other countries.

Earnings

Median annual earnings of petroleum engineers were \$78,910 in 2000. The middle 50 percent earned between \$60,610 and \$100,210. The lowest 10 percent earned less than \$48,120, and the highest 10 percent earned more than \$118,630.

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in petroleum engineering received starting offers averaging \$53,878 year and master's degree candidates, on average, were offered \$58,500.

Sources of Additional Information

For further information about petroleum engineers, contact:

► Society of Petroleum Engineers, P.O. Box 833836, Richardson, TX 75083-3836. Internet: <http://www.spe.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)

Environmental Scientists and Geoscientists

(O*NET 19-2041.00, 19-2042.01, 19-2043.00)

Significant Points

- Work at remote field sites is common.
- A bachelor's degree in geology or geophysics is adequate for entry-level jobs; better jobs with good advancement potential usually require at least a master's degree.
- A Ph.D. degree is required for most research positions in colleges and universities and in government.

Nature of the Work

Environmental scientists and geoscientists use their knowledge of the physical makeup and history of the Earth to locate water, mineral, and energy resources; protect the environment; predict future geologic hazards; and offer advice on construction and land use projects.

Environmental scientists conduct research to identify and abate or eliminate sources of pollutants that affect people, wildlife, and their environments. They analyze and report measurements and observations of air, water, soil, and other sources to make recommendations on how best to clean and preserve the environment. They often use their skills and knowledge to design and monitor waste disposal sites, preserve water supplies, and reclaim contaminated land and water to comply with Federal environmental regulations.

Geoscientists study the composition, structure, and other physical aspects of the Earth. By using sophisticated instruments and analyses of the earth and water, geoscientists study the Earth's geologic past and present in order to make predictions about its future. For example, they may study the Earth's movements to try to predict when and where the next earthquake or volcano will occur and the probable impact on surrounding areas to minimize the damage. Many geoscientists are involved in the search for oil and gas, while others work closely with environmental scientists in preserving and cleaning up the environment.

Geoscientists usually study, and are subsequently classified in, one of several closely related fields of geoscience, including geology, geophysics, and oceanography. *Geologists* study the composition, processes, and history of the Earth. They try to find out how rocks were formed and what has happened to them since formation. They also study the evolution of life by analyzing plant and animal fossils. *Geophysicists* use the principles of physics, mathematics, and chemistry to study not only the Earth's surface, but also its internal composition; ground and surface waters; atmosphere; oceans; and its magnetic, electrical, and gravitational forces. *Oceanographers* use their knowledge of geology and geophysics, in addition to biology and chemistry, to study the world's oceans and coastal waters. They study the motion and circulation of the ocean waters and their physical and chemical properties, and how these properties affect coastal areas, climate, and weather.

Geoscientists can spend a large part of their time in the field identifying and examining rocks, studying information collected by remote sensing instruments in satellites, conducting geological surveys, constructing field maps, and using instruments to measure the Earth's gravity and magnetic field. For example, they often perform seismic studies, which involve bouncing energy waves off buried rock layers, to search for oil and gas or understand the structure of subsurface rock layers. Seismic signals generated by

earthquakes are used to determine the earthquake's location and intensity.

In laboratories, geologists and geophysicists examine the chemical and physical properties of specimens. They study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks. Some geoscientists use two- or three-dimensional computer modeling to portray water layers and the flow of water or other fluids through rock cracks and porous materials. They use a variety of sophisticated laboratory instruments, including x ray diffractometers, which determine the crystal structure of minerals, and petrographic microscopes, for the study of rock and sediment samples.

Geoscientists working in mining or the oil and gas industry sometimes process and interpret data produced by remote sensing satellites to help identify potential new mineral, oil, or gas deposits. Seismic technology also is an important exploration tool. Seismic waves are used to develop a three-dimensional picture of underground or underwater rock formations. Seismic reflection technology may also reveal unusual underground features that sometimes indicate accumulations of natural gas or petroleum, facilitating exploration and reducing the risks associated with drilling in previously unexplored areas.

Numerous subdisciplines or specialties fall under the two major disciplines of geology and geophysics that further differentiate the type of work geoscientists do. For example, *petroleum geologists* explore for oil and gas deposits by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation, well log data, and computers to interpret geological information. *Engineering geologists* apply geologic principles to the fields of civil and environmental engineering, offering advice on major construction projects and assisting in environmental remediation and natural hazard reduction projects. *Mineralogists* analyze and classify minerals and precious stones according to composition and structure and study their environment in order to find new mineral resources. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the Earth. *Stratigraphers* study the formation and layering of rocks to understand the environment in which they were formed. *Volcanologists* investigate volcanoes and volcanic phenomena to try to predict the potential for future eruptions and possible hazards to human health and welfare.

Geophysicists may specialize in areas such as geodesy, seismology, or magnetic geophysics. *Geodesists* study the size and shape of the Earth, its gravitational field, tides, polar motion, and rotation. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Geochemists* study the nature and distribution of chemical elements in ground water and Earth materials. *Geomagnetists* measure the Earth's magnetic field and use measurements taken over the past few centuries to devise theoretical models to explain the Earth's origin. *Paleomagnetists* interpret fossil magnetization in rocks and sediments from the continents and oceans, to record the spreading of the sea floor, the wandering of the continents, and the many reversals of polarity that the Earth's magnetic field has undergone through time. Other geophysicists study atmospheric sciences and space physics. (See atmospheric scientists and physicists and astronomers elsewhere in the *Handbook*.)

Hydrology is closely related to the disciplines of geology and geophysics. *Hydrologists* study the quantity, distribution, circulation, and physical properties of underground and surface waters. They study the form and intensity of precipitation, its rate of infiltration into the soil, its movement through the Earth, and its return to the ocean and atmosphere. The work they do is particularly important in environmental preservation, remediation, and flood control.



Environmental scientists and geoscientists use a variety of sophisticated equipment.

Oceanography also has several subdisciplines. *Physical oceanographers* study the ocean tides, waves, currents, temperatures, density, and salinity. They study the interaction of various forms of energy, such as light, radar, sound, heat, and wind with the sea, in addition to investigating the relationship between the sea, weather, and climate. Their studies provide the Maritime Fleet with up-to-date oceanic conditions. *Chemical oceanographers* study the distribution of chemical compounds and chemical interactions that occur in the ocean and sea floor. They may investigate how pollution affects the chemistry of the ocean. *Geological and geophysical oceanographers* study the topographic features and the physical makeup of the ocean floor. Their knowledge can help oil and gas producers find these minerals on the bottom of the ocean. *Biological oceanographers*, often called marine biologists, study the distribution and migration patterns of the many diverse forms of sea life in the ocean. (See biological scientists elsewhere in the *Handbook*.)

Working Conditions

Some geoscientists spend the majority of their time in an office, but many others divide their time between fieldwork and office or laboratory work. Geologists often travel to remote field sites by helicopter or four-wheel drive vehicles and cover large areas on foot. An increasing number of exploration geologists and geophysicists work in foreign countries, sometimes in remote areas and under

difficult conditions. Oceanographers may spend considerable time at sea on academic research ships. Fieldwork often requires working long hours, but workers are usually rewarded by longer than normal vacations. Environmental scientists and geoscientists in research positions with the Federal Government or in colleges and universities often are required to design programs and write grant proposals in order to continue their data collection and research. Environmental scientists and geoscientists in consulting jobs face similar pressures to market their skills and write proposals to maintain steady work. Travel often is required to meet with prospective clients or investors.

Employment

Environmental scientists and geoscientists held about 97,000 jobs in 2000. Environmental scientists accounted for 64,000 of the total; geoscientists, 25,000; and hydrologists, 8,000. Many more individuals held environmental science and geoscience faculty positions in colleges and universities, but they are considered college and university faculty. (See postsecondary teachers elsewhere in the *Handbook*.)

Among salaried geoscientists, nearly 1 in 3 were employed in engineering and management services, and slightly more than 1 in 5 worked for oil and gas extraction companies or metal mining companies. The Federal Government employed about 3,100 geoscientists, including geologists, geophysicists, and oceanographers in 2000, mostly within the U.S. Department of the Interior for the U.S. Geological Survey (USGS), and the U.S. Department of Defense. More than 2,600 worked for State agencies, such as State geological surveys and State departments of conservation. About 1 geoscientist in 25 was self-employed; most were consultants to industry or government.

For environmental scientists, about 2 in 5 were employed in State and local governments, about 1 in 8 in management and public relations, 1 in 10 in engineering and architectural services, and 1 in 10 in the Federal Government. A small number were self-employed.

Nearly 1 in 3 hydrologist worked in the Federal Government in 2000. Another 1 in 5 worked in management and public relations, 1 in 6 in engineering and architectural services, and 1 in 6 for State governments.

Training, Other Qualifications, and Advancement

A bachelor's degree in geology or geophysics is adequate for some entry-level geoscientist jobs, but more job opportunities and better jobs with good advancement potential usually require at least a master's degree in geology or geophysics. Environmental scientists require at least a bachelor's degree in hydrogeology; environmental, civil, or geological engineering; or geochemistry or geology, but employers usually prefer candidates with master's degrees. A master's degree is required for most entry-level research positions in colleges and universities, Federal agencies, and State geological surveys. A Ph.D. is necessary for most high-level research positions.

Hundreds of colleges and universities offer a bachelor's degree in geology; fewer schools offer programs in geophysics, hydrogeology, or other geosciences. Other programs offering related training for beginning geological scientists include geophysical technology, geophysical engineering, geophysical prospecting, engineering geology, petroleum geology, geohydrology, and geochemistry. In addition, several hundred universities award advanced degrees in geology or geophysics.

Traditional geoscience courses emphasizing classical geologic methods and topics (such as mineralogy, petrology, paleontology,

stratigraphy, and structural geology) are important for all geoscientists and make up the majority of college training. Persons studying physics, chemistry, biology, mathematics, engineering, or computer science may also qualify for some environmental science and geoscience positions if their coursework includes study in geology. Those students interested in working in the environmental or regulatory fields, either in environmental consulting firms or for Federal or State governments, should take courses in hydrology, hazardous waste management, environmental legislation, chemistry, fluid mechanics, and geologic logging. An understanding of environmental regulations and government permit issues is also valuable for those planning to work in mining and oil and gas extraction. Hydrologists and environmental scientists should have some knowledge of the potential liabilities associated with some environmental work. Computer skills are essential for prospective environmental scientists and geoscientists; students who have some experience with computer modeling, data analysis and integration, digital mapping, remote sensing, and geographic information systems (GIS) will be the most prepared entering the job market. A knowledge of the Global Positioning System (GPS)—a locator system that uses satellites—also is very helpful. Some employers seek applicants with field experience, so a summer internship may be beneficial to prospective geoscientists.

Environmental scientists and geoscientists must have excellent interpersonal skills, because they usually work as part of a team with other scientists, engineers, and technicians. Strong oral and written communication skills also are important, because writing technical reports and research proposals, as well as communicating research results to others, are important aspects of the work. Because many jobs require foreign travel, knowledge of a second language is becoming an important attribute to employers. Geoscientists must be inquisitive and able to think logically and have an open mind. Those involved in fieldwork must have physical stamina.

Environmental scientists and geoscientists often begin their careers in field exploration or as research assistants or technicians in laboratories or offices. They are given more difficult assignments as they gain experience. Eventually, they may be promoted to project leader, program manager, or another management and research position.

Job Outlook

Employment of environmental scientists and hydrologists is expected to grow faster than the average for all occupations through 2010, while employment of geoscientists is expected to grow about as fast as the average. The need to replace environmental scientists and geoscientists who retire will result in many job openings over the next decade. Driving the growth of environmental scientists and geoscientists will be the continuing need for companies and organizations to comply with environmental laws and regulations, particularly those regarding groundwater contamination and flood control. However, oil company mergers and stagnant or declining government funding for research may affect the hiring of petroleum geologists and geoscientists involved in research. Instead, increased construction and exploration for oil and natural gas abroad may require geoscientists to work overseas unless additional sites in the United States are opened for exploration.

In the past, employment of geologists and some other geoscientists has been cyclical and largely affected by the price of oil and gas. When prices were low, oil and gas producers curtailed exploration activities and laid off geologists. When prices were up, companies had the funds and incentive to renew exploration efforts and hire geoscientists in large numbers. In recent years, a growing worldwide demand for oil and gas and new exploration and recovery techniques—particularly in deep water and previously inaccessible

sites—have returned some stability to the petroleum industry, with a few companies increasing their hiring of geoscientists. Growth in this area, though, will be limited due to increasing efficiencies in finding oil and gas. Geoscientists who speak a foreign language and who are willing to work abroad should enjoy the best opportunities.

The need for companies to comply with environmental laws and regulations is expected to contribute to the demand for environmental scientists and some geoscientists, especially hydrologists and engineering geologists. Issues of water conservation, deteriorating coastal environments, and rising sea levels also will stimulate employment growth of these workers. As the population increases and moves to more environmentally sensitive locations, environmental scientists and hydrologists will be needed to assess building sites for potential geologic hazards and to address issues of pollution control and waste disposal. Hydrologists and environmental scientists also will be needed to conduct research on hazardous wastesites to determine the impact of hazardous pollutants on soil and groundwater so engineers can design remediation systems. The need for environmental scientists and geoscientists who understand both the science and engineering aspects of waste remediation is growing. An expected increase in highway building and other infrastructure projects will be an additional source of jobs for engineering geologists.

Employment of environmental scientists and geoscientists is more sensitive to changes in governmental energy or environmental policy than employment of other scientists. If environmental regulations are rescinded or loosened, job opportunities will shrink. On the other hand, increased exploration for energy sources will result in improved job opportunities for geoscientists.

Jobs with the Federal and State governments and with organizations dependent on Federal funds for support will experience little growth over the next decade, unless budgets increase significantly. The Federal Government is expected to increasingly outsource environmental services to private consulting firms. This lack of funding will affect mostly geoscientists performing basic research.

Earnings

Median annual earnings of environmental scientists were \$44,180 in 2000. The middle 50 percent earned between \$34,570 and \$58,490. The lowest 10 percent earned less than \$28,520, and the highest 10 percent earned more than \$73,790.

Median annual earnings of geoscientists were \$56,230 in 2000. The middle 50 percent earned between \$43,320 and \$77,180. The lowest 10 percent earned less than \$33,910, and the highest 10 percent earned more than \$106,040.

Median annual earnings of hydrologists were \$55,410 in 2000. The middle 50 percent earned between \$43,740 and \$68,500. The lowest 10 percent earned less than \$35,910, and the highest 10 percent earned more than \$85,260.

Median annual earnings in the industries employing the largest number of environmental scientists in 2000 were as follows:

Federal Government	\$59,590
Engineering and architectural services	43,920
Management and public relations	43,900
Local government	42,880
State government	39,330

According to the National Association of Colleges and Employers, beginning salary offers in 2001 for graduates with bachelor's degrees in geology and the geological sciences averaged about \$35,568 a year; graduates with a master's degree averaged \$41,100; graduates with a doctoral degree averaged \$57,500.

In 2001, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was

\$70,763; for geophysicists, \$79,660; for hydrologists, \$64,810; and for oceanographers, \$71,881.

The petroleum, mineral, and mining industries offer higher salaries, but less job security, than other industries. These industries are vulnerable to recessions and changes in oil and gas prices, among other factors, and usually release workers when exploration and drilling slow down.

Related Occupations

Many geoscientists work in the petroleum and natural gas industry. This industry also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction, including engineering technicians, science technicians, petroleum engineers, and surveyors, cartographers and photogrammetrists. Also, some physicists, chemists, and atmospheric scientists—as well as mathematicians and systems analysts, computer scientists, and database administrators—perform related work in both petroleum and natural gas exploration and extraction and in environment-related activities.

Sources of Additional Information

Information on training and career opportunities for geologists is available from:

- American Geological Institute, 4220 King St., Alexandria, VA 22302-1502. Internet: <http://www.agiweb.org> Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140. Telephone: (717) 447-2020. Internet: <http://www.geosociety.org>.
- American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101. Internet: <http://www.aapg.org>

Information on training and career opportunities for geophysicists is available from:

- American Geophysical Union, 2000 Florida Ave. NW., Washington, DC 20009. Telephone: (202) 777-7512. Internet: <http://www.agu.org>
- Society of Exploration Geophysicists, 8801 South Yale, Tulsa, OK 74137. Telephone: (918) 497-5500. Internet: <http://www.seg.org>

A packet of free career information, and a list of education and training programs in oceanography and related fields priced at \$6.00, is available from:

- Marine Technology Society, 1828 L St. NW., Suite 906, Washington, DC 20036. Internet: <http://www.mtsociety.org>

Information on acquiring a job as a geologist, geophysicist, hydrologist, or oceanographer with the Federal Government may be obtained through a telephone-based system from the Office of Personnel Management. Consult your telephone directory under U.S. Government for a local number, or call (912) 757-3000; Federal Relay Service (800) 877-8339. This number is not tollfree, and charges may result. Information also is available from the Internet site: <http://www.usajobs.opm.gov>.

Landscape Architects

(O*NET 17-1012.00)

Significant Points

- Almost 26 percent are self-employed—nearly 4 times the proportion for all professionals.
- A bachelor's degree in landscape architecture is the minimum requirement for entry-level jobs; many employers prefer to hire landscape architects who have completed at least one internship.
- Because many landscape architects work for small firms or are self-employed, benefits tend to be less generous than those provided to workers in large organizations.

Nature of the Work

Everyone enjoys attractively designed residential areas, public parks and playgrounds, college campuses, shopping centers, golf courses, parkways, and industrial parks. Landscape architects design these areas so that they are not only functional, but also beautiful, and compatible with the natural environment. They plan the location of buildings, roads, and walkways, and the arrangement of flowers, shrubs, and trees.

Increasingly, landscape architects are becoming involved with projects in environmental remediation, such as preservation and restoration of wetlands. Historic preservation is another important objective to which landscape architects may apply their knowledge of the environment, as well as their design and artistic talents.

Many types of organizations—from real estate development firms starting new projects to municipalities constructing airports or parks—hire landscape architects, who often are involved with the development of a site from its conception. Working with architects, surveyors, and engineers, landscape architects help determine the best arrangement of roads and buildings. They also collaborate with environmental scientists, foresters, and other professionals to find the best way to conserve or restore natural resources. Once these decisions are made, landscape architects create detailed plans indicating new topography, vegetation, walkways, and other landscaping details, such as fountains and decorative features.

In planning a site, landscape architects first consider the nature and purpose of the project and the funds available. They analyze the natural elements of the site, such as the climate, soil, slope of the land, drainage, and vegetation; observe where sunlight falls on the site at different times of the day and examine the site from various angles; and assess the effect of existing buildings, roads, walkways, and utilities on the project.

After studying and analyzing the site, landscape architects prepare a preliminary design. To account for the needs of the client as well as the conditions at the site, they frequently make changes before a final design is approved. They also take into account any local, State, or Federal regulations, such as those protecting wetlands or historic resources. Computer-aided design (CAD) has become an essential tool for most landscape architects in preparing designs. Many landscape architects also use video simulation to help clients envision the proposed ideas and plans. For larger scale site planning, landscape architects also use geographic information systems technology, a computer mapping system.

Throughout all phases of the planning and design, landscape architects consult with other professionals involved in the project. Once the design is complete, they prepare a proposal for the client. They produce detailed plans of the site, including written reports, sketches, models, photographs, land-use studies, and cost estimates, and submit them for approval by the client and by regulatory agencies. When the plans are approved, landscape architects prepare working drawings showing all existing and proposed features. They also outline in detail the methods of construction and draw up a list of necessary materials.

Although many landscape architects supervise the installation of their design, some are involved in the construction of the site. However, the developer or landscape contractor usually does this.

Some landscape architects work on a variety of projects. Others specialize in a particular area, such as residential development, historic landscape restoration, waterfront improvement projects, parks and playgrounds, or shopping centers. Still others work in regional planning and resource management; feasibility, environmental impact, and cost studies; or site construction.

Most landscape architects do at least some residential work, but relatively few limit their practice to individual homeowners. Residential landscape design projects usually are too small to provide



After the plans and specifications for a project are complete, landscape architects may spend time at the site observing or supervising construction.

suitable income compared with larger commercial or multiunit residential projects. Some nurseries offer residential landscape design services, but these services often are performed by lesser qualified landscape designers, or others with training and experience in related areas.

Landscape architects who work for government agencies do site and landscape design for government buildings, parks, and other public lands, as well as park and recreation planning in national parks and forests. In addition, they prepare environmental impact statements and studies on environmental issues such as public land-use planning. Some restore degraded land, such as mines or landfills. Others architects use their skills in traffic-calming, the “art” of slowing traffic down through use of traffic design, enhancement of the physical environment, and greater attention to aesthetics.

Working Conditions

Landscape architects spend most of their time in offices creating plans and designs, preparing models and cost estimates, doing research, or attending meetings with clients and other professionals involved in a design or planning project. The remainder of their time is spent at the site. During the design and planning stage, landscape architects visit and analyze the site to verify that the design can be incorporated into the landscape. After the plans and specifications are completed, they may spend additional time at the site observing or supervising the construction. Those who work in large firms may spend considerably more time out of the office because of travel to sites outside the local area.

Salaried employees in both government and landscape architectural firms usually work regular hours; however, they may work overtime to meet a project deadline. Hours of self-employed landscape architects vary.

Employment

Landscape architects held about 22,000 jobs in 2000. About 1 out of 3 salaried workers were employed in firms that provide landscape architecture services. Architectural and engineering firms employed most of the rest. The Federal Government also employs these workers, primarily in the U.S. Departments of Agriculture, Defense, and Interior. About 1 of every 4 landscape architects were self-employed.

Employment of landscape architects is concentrated in urban and suburban areas throughout the country; some landscape architects

work in rural areas, particularly those employed by the Federal Government who plan and design parks and recreation areas.

Training, Other Qualifications, and Advancement

A bachelor’s or master’s degree in landscape architecture usually is necessary for entry into the profession. The bachelor’s degree in landscape architecture takes 4 or 5 years to complete. There are two types of accredited master’s degree programs. The master’s degree as a first professional degree is a 3-year program designed for students with an undergraduate degree in another discipline; this is the most common type. The master’s degree as the second professional degree is a 2-year program for students who have a bachelor’s degree in landscape architecture and wish to teach or specialize in some aspect of landscape architecture, such as regional planning or golf course design.

In 2000, 58 colleges and universities offered 75 undergraduate and graduate programs in landscape architecture that were accredited by the Landscape Architecture Accreditation Board of the American Society of Landscape Architects.

College courses required in this field usually include technical subjects such as surveying, landscape design and construction, landscape ecology, site design, and urban and regional planning. Other courses include history of landscape architecture, plant and soil science, geology, professional practice, and general management. Many landscape architecture programs are adding courses that address environmental issues. In addition, most students at the undergraduate level take a year of prerequisite courses such as English, mathematics, and social and physical sciences. The design studio is an important aspect of many landscape architecture curriculums. Whenever possible, students are assigned real projects, providing them with valuable hands-on experience. While working on these projects, students become more proficient in the use of computer-aided design, geographic information systems, and video simulation.

In 2000, 46 States required landscape architects to be licensed or registered. Licensing is based on the Landscape Architect Registration Examination (L.A.R.E.), sponsored by the Council of Landscape Architectural Registration Boards and administered over a 3-day period. Admission to the exam usually requires a degree from an accredited school plus 1 to 4 years of work experience, although standards vary from State to State. Currently, 16 States require the passage of a State examination in addition to the L.A.R.E. to satisfy registration requirements. State examinations, which usually are 1 hour in length and completed at the end of the L.A.R.E., focus on laws, environmental regulations, plants, soils, climate, and any other characteristics unique to the State.

Because State requirements for licensure are not uniform, landscape architects may not find it easy to transfer their registration from one State to another. However, those who meet the national standards of graduating from an accredited program, serving 3 years of internship under the supervision of a registered landscape architect, and passing the L.A.R.E. can satisfy requirements in most States. Through this means, a landscape architect can obtain certification from the Council of Landscape Architectural Registration Boards, and so gain reciprocity (the right to work) in other States.

In the Federal Government, candidates for entry positions should have a bachelor’s or master’s degree in landscape architecture. The Federal Government does not require its landscape architects to be licensed.

Persons planning a career in landscape architecture should appreciate nature, enjoy working with their hands, and possess strong analytical skills. Creative vision and artistic talent also are desirable qualities. Good oral communication skills are essential; landscape architects must be able to convey their ideas to other professionals and clients and to make presentations before large groups. Strong

writing skills also are valuable, as is knowledge of computer applications of all kinds, including word processing, desktop publishing, and spreadsheets. Landscape architects use these tools to develop presentations, proposals, reports, and land impact studies for clients, colleagues, and superiors. The ability to draft and design using CAD software is essential. Many employers recommend that prospective landscape architects complete at least one summer internship with a landscape architecture firm in order to gain an understanding of the day-to-day operations of a small business, including how to win clients, generate fees, and work within a budget.

In States where licensure is required, new hires may be called "apprentices" or "intern landscape architects" until they become licensed. Their duties vary depending on the type and size of the employing firm. They may do project research or prepare working drawings, construction documents, or base maps of the area to be landscaped. Some are allowed to participate in the actual design of a project. However, interns must perform all work under the supervision of a licensed landscape architect. Additionally, all drawings and specifications must be signed and sealed by the licensed landscape architect, who takes legal responsibility for the work. After gaining experience and becoming licensed, landscape architects usually can carry a design through all stages of development. After several years, they may become project managers, taking on the responsibility for meeting schedules and budgets, in addition to overseeing the project design; and later, associates or partners, with a proprietary interest in the business.

Many landscape architects are self-employed because start-up costs, after an initial investment in CAD software, are relatively low. Self-discipline, business acumen, and good marketing skills are important qualities for those who choose to open their own business. Even with these qualities, however, some may struggle while building a client base.

Those with landscape architecture training also qualify for jobs closely related to landscape architecture, and may, after gaining some experience, become construction supervisors, land or environmental planners, or landscape consultants.

Job Outlook

Employment of landscape architects is expected to increase faster than the average for all occupations through the year 2010. Overall, several factors are expected to increase demand for landscape architectural services over the long run: Anticipated growth in residential, commercial, and heavy construction; continued emphasis on preservation and restoration of wetlands; and growth in landscape ecology, the use of techniques from landscape architecture to address environmental problems.

Implementation of the Transportation Equity Act for the Twenty-First Century is expected to spur employment for landscape architects, particularly in State and local governments. This Act, known as TEA-21, provides funds for surface transportation and transit programs, such as interstate highway maintenance and environment-friendly pedestrian and bicycle trails. Also, growth in construction of residential and commercial building is expected to contribute to demand for landscape architects. However, opportunities will vary from year to year, and by geographic region, depending on local economic conditions. During a recession, when real estate sales and construction slow down, landscape architects may face layoffs and greater competition for jobs. The need to replace landscape architects who retire or leave the labor force for other reasons is expected to produce nearly as many job openings as employment growth.

As the cost of land rises, the importance of good site planning and landscape design grows. Increasingly, new development is contingent upon compliance with environmental regulations and land use zoning, spurring demand for landscape architects to help plan

sites and integrate man-made structures with the natural environment in the least disruptive way.

Budget tightening in the Federal Government might restrict hiring in the U.S. Forest Service and the National Park Service, agencies that traditionally employ the most landscape architects in the Federal Government. Instead, such agencies may increasingly contract out for landscape architecture services, providing additional employment opportunities in private landscape architecture firms.

In addition to the work related to new development and construction, landscape architects are expected to be involved in historic preservation, land reclamation, and refurbishment of existing sites. Because landscape architects can work on many different types of projects, they may have an easier time than other design professionals finding employment when traditional construction slows down.

New graduates can expect to face competition for jobs in the largest and most prestigious landscape architecture firms. The number of professional degrees awarded in landscape architecture has remained steady over the years, even during times of fluctuating demand due to economic conditions. Opportunities will be best for landscape architects who develop strong technical skills—such as computer design—and communication skills, as well as knowledge of environmental codes and regulations. Those with additional training or experience in urban planning increase their opportunities for employment in landscape architecture firms that specialize in site planning as well as landscape design. Many employers prefer to hire entry-level landscape architects who have internship experience, which significantly reduces the amount of on-the-job training required.

Earnings

In 2000, median annual earnings for landscape architects were \$43,540. The middle 50 percent earned between \$32,990 and \$59,490. The lowest 10 percent earned less than \$26,300 and the highest 10 percent earned over \$74,100. Landscape and horticultural services employed more landscape architects than any other industry, and their median annual earnings were \$37,820 in 2000.

In 2001, the average annual salary for all landscape architects in the Federal Government in nonsupervisory, supervisory, and managerial positions was \$62,824.

Because many landscape architects work for small firms or are self-employed, benefits tend to be less generous than those provided to workers in large organizations.

Related Occupations

Landscape architects use their knowledge of design, construction, land-use planning, and environmental issues to develop a landscape project. Others whose work requires similar skills are architects, except landscape and naval; surveyors, cartographers, photogrammetrists, and surveying technicians; civil engineers; and urban and regional planners. Landscape architects also know how to grow and use plants in the landscape. Some conservation scientists and foresters and biological and medical scientists study plants in general and do related work, while environmental scientists and geoscientists work in the area of environmental remediation.

Sources of Additional Information

Additional information, including a list of colleges and universities offering accredited programs in landscape architecture, is available from:

► American Society of Landscape Architects, Career Information, 636 Eye St. NW., Washington, DC 20001. Internet: <http://www.asla.org>

General information on registration or licensing requirements is available from:

► Council of Landscape Architectural Registration Boards, 12700 Fair Lakes Circle, Suite 110, Fairfax, VA 22033. Internet: <http://www.clarb.org>

Physicists and Astronomers

(O*NET 19-2011.00, 19-2012.00)

Significant Points

- A doctoral degree is the usual educational requirement because most jobs are in basic research and development; a bachelor's or master's degree is sufficient for some jobs in applied research and development.
- Because funding for research grows slowly, new Ph.D. graduates will face competition for basic research jobs.

Nature of the Work

Physicists explore and identify basic principles governing the structure and behavior of matter, the generation and transfer of energy, and the interaction of matter and energy. Some physicists use these principles in theoretical areas, such as the nature of time and the origin of the universe; others apply their physics knowledge to practical areas, such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, cyclotrons, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover and explain laws describing the forces of nature, such as gravity, electromagnetism, and nuclear interactions. Physicists also find ways to apply physical laws and theories to problems in nuclear energy, electronics, optics, materials, communications, aerospace technology, navigation equipment, and medical instrumentation.

Astronomy is sometimes considered a subfield of physics. *Astronomers* use the principles of physics and mathematics to learn about the fundamental nature of the universe, including the sun, moon, planets, stars, and galaxies. They also apply their knowledge to solve problems in navigation, space flight, and satellite communications, and to develop the instrumentation and techniques used to observe and collect astronomical data.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For example, basic research in solid-state physics led to the development of transistors and, then, of integrated circuits used in computers.

Physicists also design research equipment. This equipment often has additional unanticipated uses. For example, lasers are used in surgery, microwave devices are used in ovens, and measuring instruments can analyze blood or the chemical content of foods. A small number of physicists work in inspection, testing, quality control, and other production-related jobs in industry.

Much physics research is done in small or medium-size laboratories. However, experiments in plasma, nuclear, and high energy and in some other areas of physics require extremely large, expensive equipment, such as particle accelerators. Physicists in these subfields often work in large teams. Although physics research may require extensive experimentation in laboratories, research physicists still spend time in offices planning, recording, analyzing, and reporting on research.

Almost all astronomers do research. Some are theoreticians, working on the laws governing the structure and evolution of astronomical objects. Others analyze large quantities of data gathered by observatories and satellites, and write scientific papers or reports on their findings. Some astronomers actually operate, usually as



A doctoral degree usually is necessary for most basic research and development positions.

part of a team, large space- or ground-based telescopes. However, astronomers may spend only a few weeks each year making observations with optical telescopes, radio telescopes, and other instruments. For many years, satellites and other space-based instruments have provided tremendous amounts of astronomical data. New technology resulting in improvements in analytical techniques and instruments, such as computers and optical telescopes and mounts, is leading to a resurgence in ground-based research. A small number of astronomers work in museums housing planetariums. These astronomers develop and revise programs presented to the public and may direct planetarium operations.

Physicists generally specialize in one of many subfields—elementary particle physics, nuclear physics, atomic and molecular physics, physics of condensed matter (solid-state physics), optics, acoustics, space physics, plasma physics, or the physics of fluids. Some specialize in a subdivision of one of these subfields. For example, within condensed matter physics, specialties include superconductivity, crystallography, and semiconductors. However, all physics involves the same fundamental principles, so specialties may overlap, and physicists may switch from one subfield to another. Also, growing numbers of physicists work in combined fields, such as biophysics, chemical physics, and geophysics.

Working Conditions

Physicists often work regular hours in laboratories and offices. At times, however, those who are deeply involved in research may work

long or irregular hours. Most do not encounter unusual hazards in their work. Some physicists temporarily work away from home at national or international facilities with unique equipment, such as particle accelerators. Astronomers who make observations using ground-based telescopes may spend long periods in observatories; this work usually involves travel to remote locations. Long hours, including routine night work, may create temporarily stressful conditions.

Physicists and astronomers whose work is dependent on grant money often are under pressure to write grant proposals to keep their work funded.

Employment

Physicists and astronomers held about 10,000 jobs in 2000. Jobs for astronomers accounted for only a small number—10 percent—of the total. About 40 percent of all nonfaculty physicists and astronomers worked for commercial or noncommercial research, development, and testing laboratories. The Federal Government employed almost 35 percent, mostly in the U.S. Department of Defense, but also in the National Aeronautics and Space Administration (NASA), and in the U.S. Departments of Commerce, Health and Human Services, and Energy. Other physicists and astronomers worked in colleges and universities in nonfaculty positions, or for State governments, drug companies, or electronic equipment manufacturers.

Besides the jobs described above, many physicists and astronomers held faculty positions in colleges and universities. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

Although physicists and astronomers are employed in all parts of the country, most work in areas in which universities, large research and development laboratories, or observatories are located.

Training, Other Qualifications, and Advancement

Because most jobs are in basic research and development, a doctoral degree is the usual educational requirement for physicists and astronomers. Additional experience and training in a postdoctoral research appointment, although not required, is important for physicists and astronomers aspiring to permanent positions in basic research in universities and government laboratories. Many physics and astronomy Ph.D.-holders ultimately teach at the college or university level.

Master's degree holders usually do not qualify for basic research positions but do qualify for many kinds of jobs requiring a physics background, including positions in manufacturing and applied research and development. Physics departments in some colleges and universities are creating professional master's degree programs to specifically prepare students for physics-related research and development in private industry that do not require a Ph.D. degree. A master's degree may suffice for teaching jobs in 2-year colleges. Those with bachelor's degrees in physics are rarely qualified to fill positions as research or teaching physicists. They are, however, usually qualified to work in engineering-related areas, in software development and other scientific fields, as technicians, or to assist in setting up computer networks and sophisticated laboratory equipment. Some may qualify for applied research jobs in private industry or nonresearch positions in the Federal Government. Some become science teachers in secondary schools. Astronomy bachelor's or master's degree holders often enter a field unrelated to astronomy, and they are qualified to work in planetariums running science shows, to assist astronomers doing research, and to operate space- and ground-based telescopes and other astronomical instrumentation. (See the statements on engineers; geologists, geophysicists, and oceanographers; computer programmers; and computer systems analysts, engineers, and scientists elsewhere in the *Handbook*.)

About 507 colleges and universities offer a bachelor's degree in physics. Undergraduate programs provide a broad background in the natural sciences and mathematics. Typical physics courses include electromagnetism, optics, thermodynamics, atomic physics, and quantum mechanics.

In 2000, 183 colleges and universities had departments offering Ph.D. degrees in physics. Another 72 departments offered a master's as their highest degree. Graduate students usually concentrate in a subfield of physics, such as elementary particles or condensed matter. Many begin studying for their doctorate immediately after receiving their bachelor's degree.

About 69 universities grant degrees in astronomy, either through an astronomy, physics, or combined physics/astronomy department. Applicants to astronomy doctoral programs face competition for available slots. Those planning a career in astronomy should have a very strong physics background. In fact, an undergraduate degree in either physics or astronomy is excellent preparation, followed by a Ph.D. in astronomy.

Mathematical ability, problem-solving and analytical skills, an inquisitive mind, imagination, and initiative are important traits for anyone planning a career in physics or astronomy. Prospective physicists who hope to work in industrial laboratories applying physics knowledge to practical problems should broaden their educational background to include courses outside of physics, such as economics, computer technology, and business management. Good oral and written communication skills also are important because many physicists work as part of a team, write research papers or proposals, or have contact with clients or customers with nonphysics backgrounds.

Many physics and astronomy Ph.D.'s begin their careers in a postdoctoral research position, where they may work with experienced physicists as they continue to learn about their specialty and develop ideas and results to be used in later work. Initial work may be under the close supervision of senior scientists. After some experience, physicists perform increasingly complex tasks and work more independently. Those who develop new products or processes sometimes form their own companies or join new firms to exploit their own ideas.

Job Outlook

Historically, many physicists and astronomers have been employed on research projects—often defense-related. Because defense expenditures are expected to increase over the next decade, employment of physicists and astronomers is projected to grow about as fast as the average for all occupations, through the year 2010. The need to replace physicists and astronomers who retire will, however, account for most expected job openings. The Federal Government funds numerous noncommercial research facilities. The Federally Funded Research and Development Centers (FFRDCs), whose missions include a significant physics component, are largely funded by the Department of Energy (DOE) or the Department of Defense (DOD), and their R&D budgets did not keep pace with inflation during much of the 1990s. However, Federal budgets have recently increased for physics-related research at these centers, as well as other agencies such as NASA. If R&D funding continues to grow at these agencies, job opportunities for physicists and astronomers, especially those dependent on Federal research grants, should be better than they have been in many years.

Although research and development budgets in private industry will continue to grow, many research laboratories in private industry are expected to continue to reduce basic research, which includes much physics research, in favor of applied or manufacturing research and product and software development. Nevertheless, many persons with a physics background continue to be in demand in the areas of information technology, semiconductor technology,

and other applied sciences. This trend is expected to continue; however, many of these positions will be under job titles such as computer software engineer, computer programmer, engineer, and systems developer, rather than physicist.

For several years, the number of doctorates granted in physics has been much greater than the number of openings for physicists, resulting in keen competition, particularly for research positions in colleges and universities and in research and development centers. Competitive conditions are beginning to ease, because the number of doctorate degrees awarded has begun dropping, following recent declines in enrollment in graduate physics programs. However, new doctoral graduates should still expect to face competition for research jobs, not only from fellow graduates, but also from an existing supply of postdoctoral workers seeking to leave low-paying, temporary positions and non-U.S. citizen applicants.

Opportunities may be more numerous for those with a master's degree, particularly graduates from programs preparing students for applied research and development, product design, and manufacturing positions in industry. Many of these positions, however, will have titles other than physicist, such as engineer or computer scientist.

Persons with only a bachelor's degree in physics or astronomy are not qualified to enter most physicist or astronomer research jobs but may qualify for a wide range of positions in engineering, technician, mathematics, and computer- and environment-related occupations. Those who meet State certification requirements can become high school physics teachers, an occupation reportedly in strong demand in many school districts. (See the statements on these occupations elsewhere in the *Handbook*.) Despite competition for traditional physics and astronomy research jobs, individuals with a physics degree at any level will find their skills useful for entry to many other occupations.

Earnings

Median annual earnings of physicists and astronomers in 2000 were \$82,535. Median annual earnings of astronomers were \$74,510, while physicists earned \$83,310. The middle 50 percent of physicists earned between \$65,820 and \$102,270. The lowest 10 percent earned less than \$51,680, and the highest 10 percent earned more than \$116,290.

According to a 2001 National Association of Colleges and Employers survey, the average annual starting salary offer to physics doctoral degree candidates was \$68,273.

The American Institute of Physics reported a median annual salary of \$78,000 in 2000 for its members with Ph.D's (excluding those in postdoctoral positions); with master's degrees, \$63,800; and with bachelor's degrees, \$60,000. Those working in temporary postdoctoral positions earned significantly less.

The average annual salary for physicists employed by the Federal Government was \$86,799 in 2001; for astronomy and space scientists, \$89,734.

Related Occupations

The work of physicists and astronomers relates closely to that of engineers, chemists, atmospheric scientists, computer scientists, computer programmers, and mathematicians.

Sources of Additional Information

General information on career opportunities in physics is available from:

- ▶ American Institute of Physics, Career Services Division and Education and Employment Division, One Physics Ellipse, College Park, MD 20740-3843. Internet: <http://www.aip.org>
- ▶ The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844. Internet: <http://www.aps.org>

Science Technicians

(O*NET 19-4011.01, 19-4011.02, 19-4021.00, 19-4031.00, 19-4041.01, 19-4041.02, 19-4051.01, 19-4051.02, 19-4091.00, 19-4092.00, 19-4093.00)

Significant Points

- Science technicians in production jobs often work in 8-hour shifts around the clock.
- Job opportunities are expected to be best for qualified graduates of science technician training programs or applied science technology programs.

Nature of the Work

Science technicians use the principles and theories of science and mathematics to solve problems in research and development and to help invent and improve products and processes. However, their jobs are more practically oriented than those of scientists. Technicians set up, operate, and maintain laboratory instruments, monitor experiments, make observations, calculate and record results, and often develop conclusions. They must keep detailed logs of all their work-related activities. Those who work in production monitor manufacturing processes and may be involved in ensuring quality by testing products for proper proportions of ingredients, purity, or for strength and durability.

As laboratory instrumentation and procedures have become more complex in recent years, the role of science technicians in research and development has expanded. In addition to performing routine tasks, many technicians also develop and adapt laboratory procedures to achieve the best results, interpret data, and devise solutions to problems, under the direction of scientists. Moreover, technicians must master the laboratory equipment so that they can adjust settings when necessary and recognize when equipment is malfunctioning.

The increasing use of robotics to perform many routine tasks has freed technicians to operate more sophisticated laboratory equipment. Science technicians make extensive use of computers, computer-interfaced equipment, robotics, and high-technology industrial applications, such as biological engineering.

Most science technicians specialize, learning skills and working in the same disciplines as scientists. Occupational titles, therefore, tend to follow the same structure as scientists. *Agricultural technicians* work with agricultural scientists in food, fiber, and animal research, production, and processing. Some conduct tests and experiments to improve the yield and quality of crops or to increase the resistance of plants and animals to disease, insects, or other hazards. Other agricultural technicians do animal breeding and nutrition work. *Food science technicians* assist food scientists and technologists in research and development, production technology, and quality control. For example, food science technicians may conduct tests on food additives and preservatives to ensure FDA compliance on factors such as color, texture, and nutrients. They analyze, record, and compile test results; order supplies to maintain laboratory inventory; and clean and sterilize laboratory equipment.

Biological technicians work with biologists studying living organisms. Many assist scientists who conduct medical research—helping to find a cure for cancer or AIDS, for example. Those who work in pharmaceutical companies help develop and manufacture medicinal and pharmaceutical preparations. Those working in the field of microbiology generally work as lab assistants, studying living organisms and infectious agents. Biological technicians also

analyze organic substances, such as blood, food, and drugs, and some examine evidence in criminal investigations. Biological technicians working in biotechnology labs use the knowledge and techniques gained from basic research by scientists, including gene splicing and recombinant DNA, and apply these techniques in product development.

Chemical technicians work with chemists and chemical engineers, developing and using chemicals and related products and equipment. Most do research and development, testing, or other laboratory work. For example, they might test packaging for design, integrity of materials, and environmental acceptability; assemble and operate new equipment to develop new products; monitor product quality; or develop new production techniques. Some chemical technicians collect and analyze samples of air and water to monitor pollution levels. Those who focus on basic research might produce compounds through complex organic synthesis. Chemical technicians within chemical plants are also referred to as *process technicians*. They may operate equipment, monitor plant processes and analyze plant materials.

Environmental science and protection technicians perform laboratory and field tests to monitor environmental resources and determine the contaminants and sources of pollution. They may collect samples for testing or be involved in abating, controlling, or remediating sources of environmental pollutants. Some are responsible for waste management operations, control and management of hazardous materials inventory, or general activities involving regulatory compliance. There is a growing emphasis on pollution prevention activities.

Forensic science technicians investigate crimes by collecting and analyzing physical evidence. Often, they specialize in areas such as DNA analysis or firearm examination, performing tests on weapons or substances, such as fiber, hair, tissue, or body fluids to determine significance to the investigation. They also prepare reports to document their findings and the laboratory techniques used. When criminal cases come to trial, forensic science technicians often provide testimony, as expert witnesses, on specific laboratory findings by identifying and classifying substances, materials, and other evidence collected at the crime scene.

Forest and conservation technicians compile data on the size, content, and condition of forest land tracts. These workers travel through sections of forest to gather basic information, such as species and population of trees, disease and insect damage, tree seedling mortality, and conditions that may cause fire danger. Forest

and conservation technicians also train and lead forest and conservation workers in seasonal activities, such as planting tree seedlings, putting out forest fires, and maintaining recreational facilities.

Geological and petroleum technicians measure and record physical and geologic conditions in oil or gas wells, using instruments lowered into wells or by analysis of the mud from wells. In oil and gas exploration, these technicians collect and examine geological data or test geological samples to determine petroleum and mineral content. Some petroleum technicians, called *scouts*, collect information about oil and gas well drilling operations, geological and geophysical prospecting, and land or lease contracts.

Nuclear technicians operate nuclear test and research equipment, monitor radiation, and assist nuclear engineers and physicists in research. Some also operate remote control equipment to manipulate radioactive materials or materials to be exposed to radioactivity.

Other science technicians collect weather information or assist oceanographers.

Working Conditions

Science technicians work under a wide variety of conditions. Most work indoors, usually in laboratories, and have regular hours. Some occasionally work irregular hours to monitor experiments that can not be completed during regular working hours. Production technicians often work in 8-hour shifts around the clock. Others, such as agricultural, forest and conservation, geological and petroleum, and environmental science and protection technicians, perform much of their work outdoors, sometimes in remote locations.

Some science technicians may be exposed to hazards from equipment, chemicals, or toxic materials. Chemical technicians sometimes work with toxic chemicals or radioactive isotopes, nuclear technicians may be exposed to radiation, and biological technicians sometimes work with disease-causing organisms or radioactive agents. Forensic science technicians often are exposed to human body fluids and firearms. However, these working conditions pose little risk, if proper safety procedures are followed. For forensic science technicians, collecting evidence from crime scenes can be distressing and unpleasant.

Employment

Science technicians held about 198,000 jobs in 2000. Employment was distributed as follows:

Chemical technicians	73,000
Biological technicians	41,000
Environmental science and protection technicians, including health	27,000
Forest and conservation technicians	18,000
Agricultural and food science technicians	18,000
Geological and petroleum technicians	10,000
Forensic science technicians	6,400
Nuclear technicians	3,300

Chemical technicians held jobs in a wide range of manufacturing and service industries, but were concentrated in chemical manufacturing, where they held over 30,000 jobs. A significant number, 12,000, worked in research and testing firms. About 45 percent of biological technicians also worked in research and testing firms. Most of the rest of biological technicians worked in drug manufacturing or for Federal, State, or local governments. Significant numbers of environmental science and protection technicians also worked for State and local governments and research and testing services. Others worked for engineering and architectural services and management and public relations firms. Nearly 68 percent of forest and conservation technicians held jobs in Federal Government; another 22 percent worked for State governments. More than 30 percent of



Environmental science technicians perform laboratory tests to determine the presence or absence of various contaminants.

agricultural and food science technicians worked for food processing companies; the rest worked for research and testing firms, State governments, and non-veterinary animal services. More than 47 percent of geological and petroleum technicians worked for oil and gas extraction companies, and forensic science technicians worked primarily for State and local governments.

Training, Other Qualifications, and Advancement

There are several ways to qualify for a job as a science technician. Many employers prefer applicants who have at least 2 years of specialized training or an associate degree in applied science or science-related technology. Because employers' preferences vary, however, some science technicians have a bachelor's degree in chemistry, biology, or forensic science, or have taken several science and math courses at 4-year colleges.

Many technical and community colleges offer associate degrees in a specific technology or a more general education in science and mathematics. A number of 2-year associate degree programs are designed to provide easy transfer to a 4-year college or university, if desired. Technical institutes usually offer technician training, but provide less theory and general education than technical or community colleges. The length of programs at technical institutes varies, although 1-year certificate programs and 2-year associate degree programs are common.

About 20 colleges or universities offer bachelor's degree programs in forensic technology, often with an emphasis in a specialty area, such as criminalistics, pathology, jurisprudence, odontology, or toxicology. In contrast to some other science technician positions that require only a 2-year degree, a 4-year degree in forensics science is usually necessary to work in the field. Forestry and conservation technicians can choose from 23 associate degree programs accredited by the Society of American Foresters.

Some schools offer cooperative-education or internship programs, allowing students the opportunity to work at a local company or other workplace, while attending classes in alternate terms. Participation in such programs can significantly enhance a student's employment prospects.

Persons interested in careers as science technicians should take as many high school science and math courses as possible. Science courses taken beyond high school, in an associate's or bachelor's program, should be laboratory oriented, with an emphasis on bench skills. Because computers and computer-interfaced equipment often are used in research and development laboratories, technicians should have strong computer skills. Communication skills are also important; technicians often are required to report their findings both through speaking and in writing. Additionally, technicians should be able to work well with others, because teamwork is common. Organizational ability, an eye for detail, and skill in interpreting scientific results are also important.

Prospective science technicians can acquire good career preparation through 2-year formal training programs that combine the teaching of scientific principles and theory with practical hands-on application in a laboratory setting with up-to-date equipment. Graduates of 4-year bachelor's degree programs in science who have considerable experience in laboratory-based courses, have completed internships, or held summer jobs in laboratories, are also well-qualified for science technician positions and are preferred by some employers. However, those with a bachelor's degree who accept technician jobs generally cannot find employment that uses their advanced academic education.

Technicians usually begin work as trainees in routine positions, under the direct supervision of a scientist or a more experienced technician. Job candidates whose training or educational background encompasses extensive hands-on experience with a variety

of laboratory equipment, including computers and related equipment, usually require a short period of on-the-job training. As they gain experience, technicians take on more responsibility and carry out assignments under only general supervision, and some eventually become supervisors. However, technicians employed at universities often have their fortunes tied to particular professors; when professors retire or leave, these technicians face uncertain employment prospects.

Job Outlook

Overall employment of science technicians is expected to increase about as fast as the average for all occupations through the year 2010. Continued growth of scientific and medical research, as well as the development and production of technical products, should stimulate demand for science technicians in many industries. In particular, the growing number of agricultural and medicinal products developed from using biotechnology techniques will increase the need for biological technicians. Also, stronger competition among drug companies and an aging population are expected to contribute to the need for innovative and improved drugs, further spurring demand for biological technicians. Fastest employment growth of biological technicians should occur in the drug manufacturing industry and research and testing service firms.

The chemical and drug industry, the major employers of chemical technicians, should face stable demand for new and better pharmaceuticals and personal care products. To meet these demands, chemical and drug manufacturing firms are expected to continue to devote money to research and development, either through in-house teams or outside contractors, spurring employment growth of chemical technicians. An increasing focus on quality assurance will further stimulate demand for these workers. However, growth will be moderated somewhat by an expected slowdown in overall employment in the chemical industry.

Overall employment growth of science technicians will also be fueled by demand for environmental technicians to help regulate waste products; to collect air, water, and soil samples for measuring levels of pollutants; to monitor compliance with environmental regulations; and to clean up contaminated sites.

Demand for forest and conservation technicians at the Federal and State government levels will result from a continuing emphasis on sustainability issues, such as environmental protection and responsible land management. However, employment growth may be moderated by downsizing in the Federal Government and continuing reductions in timber harvesting on Federal lands.

Agricultural and food science technicians will be needed to assist agricultural scientists in biotechnology research as it becomes increasingly important to balance greater agricultural output with protection and preservation of soil, water, and the ecosystem. Jobs for forensic science technicians are expected to grow slowly. Crime scene technicians who work for State Public Safety Departments may experience favorable employment prospects if the number of qualified applicants remains low.

Job opportunities are expected to be best for qualified graduates of science technician training programs or applied science technology programs who are well-trained on equipment used in industrial and government laboratories and production facilities. As the instrumentation and techniques used in industrial research, development, and production become increasingly more complex, employers are seeking well-trained individuals with highly developed technical and communication skills.

Along with opportunities created by growth, many job openings should arise from the need to replace technicians who retire or leave the labor force for other reasons. During periods of economic recession, layoffs of science technicians may occur.

Earnings

Median hourly earnings of science technicians in 2000 were as follows:

Nuclear technicians	\$28.44
Forensic science technicians	18.04
Geological and petroleum technicians	17.55
Chemical technicians	17.05
Environmental science and protection technicians, including health.....	16.26
Biological technicians	15.16
Forest and conservation technicians	14.22
Agricultural and food science technicians	13.02

In the Federal Government in 2001, science technicians started at \$17,483, \$19,453, or \$22,251, depending on education and experience. Beginning salaries were slightly higher in selected areas of the country where the prevailing local pay level was higher. The average annual salary for biological science technicians in nonsupervisory, supervisory, and managerial positions employed by the Federal Government in 2001 was \$32,753; for physical science technicians, \$42,657; for geodetic technicians, \$53,143; for hydrologic technicians, \$39,518; and for meteorologic technicians, \$48,630.

Related Occupations

Other technicians who apply scientific principles at a level usually taught in 2-year associate degree programs include engineering technicians, broadcast technicians and sound engineering technicians and radio operators, drafters, and various health technologists and technicians, including clinical laboratory technologists and technicians, diagnostic medical sonographers, and radiologic technologists and technicians.

Sources of Additional Information

For information about a career as a chemical technician, contact:

➤ American Chemical Society, Education Division, Career Publications, 1155 16th St. NW., Washington, DC 20036. Internet: <http://www.acs.org>

For career information and a list of undergraduate, graduate, and doctoral programs in forensics sciences, contact:

➤ American Academy of Forensic Sciences, P.O. BOX 669, Colorado Springs, CO, 80901. Internet: <http://www.aafs.org>

For information on forestry technicians and lists of schools offering education in forestry, send a self-addressed, stamped business envelope to:

➤ Society of American Foresters, 5400 Grosvenor Ln., Bethesda, MD 20814. Internet: <http://www.safnet.org>

Surveyors, Cartographers, Photogrammetrists, and Surveying Technicians

(O*NET 17-1021.00, 17-1022.00, 17-3031.01, 17-3031.02)

Significant Points

- Four out of 5 are employed in engineering services and in government.
- Computer skills enhance employment opportunities.

Nature of the Work

Measuring and mapping the earth's surface are the responsibilities of several different types of workers. Traditional *land surveyors* establish official land, air space, and water boundaries. They write

descriptions of land for deeds, leases, and other legal documents; define air space for airports; and measure construction and mineral sites. Other surveyors provide data relevant to the shape, contour, location, elevation, or dimension of land or land features. *Cartographers* compile geographic, political, and cultural information and prepare maps of large areas. *Photogrammetrists* measure and analyze aerial photographs to prepare detailed maps and drawings. *Surveying technicians* assist land surveyors by operating survey instruments and collecting information in the field, and by performing computations and computer-aided drafting in offices. *Mapping technicians* calculate mapmaking information from field notes. They also draw topographical maps and verify their accuracy.

Land surveyors manage survey parties who measure distances, directions, and angles between points and elevations of points, lines, and contours on, above, and below the earth's surface. They plan the fieldwork, select known survey reference points, and determine the precise location of important features in the survey area. Surveyors research legal records, look for evidence of previous boundaries, and analyze the data to determine the location of boundary lines. They also record the results of the survey, verify the accuracy of data, and prepare plots, maps, and reports. Surveyors who establish boundaries must be licensed by the State in which they work, and are known as Professional Land Surveyors. Professional Land Surveyors are sometimes called to provide expert testimony in court cases concerning surveying matters.

A survey party gathers the information needed by the land surveyor. A typical survey party consists of a party chief and one or more surveying technicians and helpers. The party chief, who may be either a land surveyor or a senior surveying technician, leads day-to-day work activities. Surveying technicians assist the party chief by adjusting and operating surveying instruments, such as the theodolite (used to measure horizontal and vertical angles) and electronic distance-measuring equipment. Surveying technicians or assistants position and hold the vertical rods, or targets, that the theodolite operator sights on to measure angles, distances, or elevations. They also may hold measuring tapes, if electronic distance-measuring equipment is not used. Surveying technicians compile notes, make sketches, and enter the data obtained from surveying instruments into computers. Survey parties may include laborers or helpers who perform less-skilled duties, such as clearing brush from sight lines, driving stakes, or carrying equipment.

New technology is changing the nature of the work of surveyors and surveying technicians. For larger projects, surveyors are increasingly using the Global Positioning System (GPS), a satellite system that precisely locates points on the earth by using radio signals transmitted via satellites. To use this system, a surveyor places a satellite signal receiver—a small instrument mounted on a tripod—on a desired point. The receiver simultaneously collects information from several satellites to establish a precise position. The receiver also can be placed in a vehicle for tracing out road systems. Because receivers now come in different sizes and shapes and the cost of the receivers has fallen, much more surveying work is being done using GPS. Surveyors then must interpret and check the results produced by the new technology.

Cartographers measure, map, and chart the earth's surface, which involves everything from geographical research and data compilation to actual map production. They collect, analyze, and interpret both spatial data—such as latitude, longitude, elevation, and distance—and nonspatial data—such as population density, land use patterns, annual precipitation levels, and demographic characteristics. Cartographers prepare maps in either digital or graphic form, using information provided by geodetic surveys, aerial photographs, and satellite data. *Photogrammetrists* prepare detailed maps and drawings from aerial photographs, usually of areas that



After completing fieldwork, surveyors record the results of their survey as plots, maps, and reports.

are inaccessible, difficult, or less cost-efficient to survey by other methods. *Map editors* develop and verify map contents from aerial photographs and other reference sources. Some States require photogrammetrists to be licensed as Professional Land Surveyors.

Some surveyors perform specialized functions that are closer to those of a cartographer than to those of a traditional surveyor. For example, *geodetic surveyors* use high-accuracy techniques, including satellite observations (remote sensing), to measure large areas of the earth's surface. *Geophysical prospecting* surveyors mark sites for subsurface exploration, usually petroleum related. *Marine or hydrographic surveyors* survey harbors, rivers, and other bodies of water to determine shorelines, topography of the bottom, water depth, and other features.

The work of surveyors and cartographers is changing because of advancements in technology. These advancements include not only the GPS, but also new earth resources data satellites, improved aerial photography, and geographic information systems (GIS)—which are computerized data banks of spatial data. From the older specialties of photogrammetrist and cartographer, a new type of mapping scientist is emerging. The *geographic information specialist* combines the functions of mapping science and surveying into a broader field concerned with the collection and analysis of geographic information.

Working Conditions

Surveyors usually work an 8-hour day, 5 days a week, and may spend a lot of time outdoors. Sometimes they work longer hours during the summer, when weather and light conditions are most suitable for fieldwork. Seasonal demands for longer hours are related to demand for specific surveying services. Home purchases are traditionally related to the start and end of the school year; construction is related to the materials to be used (concrete and asphalt are restricted by outside temperatures, unlike wood framing); and aerial photography is most effective when the leaves are off the trees.

Land surveyors and technicians engage in active, and sometimes strenuous, work. They often stand for long periods, walk considerable distances, and climb hills with heavy packs of instruments and other equipment. They can also be exposed to all types of weather. Traveling often is part of the job; they may commute long distances, stay overnight, or temporarily relocate near a survey site.

While surveyors can spend considerable time indoors planning surveys, analyzing data, and preparing reports and maps,

cartographers spend virtually all of their time in offices and seldom visit the sites they are mapping.

Employment

Surveyors, cartographers, photogrammetrists, and surveying technicians held about 121,000 jobs in 2000. Engineering and architectural services firms employed about 63 percent of these workers. Federal, State, and local governmental agencies employed an additional 16 percent. Major Federal Government employers are the U.S. Geological Survey (USGS), the Bureau of Land Management (BLM), the Army Corps of Engineers, the Forest Service (USFS), the National Oceanic and Atmospheric Administration (NOAA), the National Imagery and Mapping Agency (NIMA), and the Federal Emergency Management Agency (FEMA). Most surveyors in State and local government work for highway departments and urban planning and redevelopment agencies. Construction firms, mining and oil and gas extraction companies, and public utilities also employ surveyors, cartographers, photogrammetrists, and surveying technicians. About 5,000 were self-employed in 2000.

Training, Other Qualifications, and Advancement

Most people prepare for a career as a licensed surveyor by combining postsecondary school courses in surveying with extensive on-the-job training. However, as technology advances, a 4-year college degree is becoming more of a prerequisite. About 25 universities now offer 4-year programs leading to a B.S. degree in surveying. Junior and community colleges, technical institutes, and vocational schools offer 1-, 2-, and 3-year programs in both surveying and surveying technology.

All 50 States and all U.S. territories (Puerto Rico, Guam, Marianna Islands, and Virgin Islands) license land surveyors. For licensure, most State licensing boards require that individuals pass a written examination given by the National Council of Examiners for Engineering and Surveying. Most States also require that surveyors pass a written examination prepared by the State licensing board. In addition, they must meet varying standards of formal education and work experience in the field. In the past, many individuals started as members of survey crews and worked their way up to become licensed surveyors with little formal training in surveying. However, because of advancing technology and rising licensing standards, formal education requirements are increasing. At present, most States require some formal post-high school coursework and 10 to 12 years of surveying experience to gain licensure. However, requirements vary among States. Generally, the quickest route to licensure is a combination of 4 years of college, 2 to 4 years of experience (a few States do not require any), and passing the licensing examinations. An increasing number of States require a bachelor's degree in surveying or in a closely related field, such as civil engineering or forestry (with courses in surveying), regardless of the number of years of experience.

High school students interested in surveying should take courses in algebra, geometry, trigonometry, drafting, mechanical drawing, and computer science. High school graduates with no formal training in surveying usually start as apprentices. Beginners with postsecondary school training in surveying usually can start as technicians or assistants. With on-the-job experience and formal training in surveying—either in an institutional program or from a correspondence school—workers may advance to senior survey technician, then to party chief, and in some cases, to licensed surveyor (depending on State licensing requirements).

The National Society of Professional Surveyors, a member organization of the American Congress on Surveying and Mapping, has

a voluntary certification program for surveying technicians. Technicians are certified at four levels requiring progressive amounts of experience, in addition to the passing of written examinations. Although not required for State licensure, many employers require certification for promotion to positions with greater responsibilities.

Surveyors should have the ability to visualize objects, distances, sizes, and abstract forms. They must work with precision and accuracy because mistakes can be costly. Members of a survey party must be in good physical condition because they work outdoors and often carry equipment over difficult terrain. They need good eyesight, coordination, and hearing to communicate verbally and manually (using hand signals). Surveying is a cooperative process, so good interpersonal skills and the ability to work as part of a team are important. Good office skills are also essential. Surveyors must be able to research old deeds and other legal documents and prepare reports that document their work.

Cartographers and photogrammetrists usually have a bachelor's degree in a field such as engineering, forestry, geography, or a physical science. Although it is possible to enter these positions through previous experience as a photogrammetric or cartographic technician, most cartographic and photogrammetric technicians now have had some specialized postsecondary school training. With the development of GIS, cartographers and photogrammetrists need additional education and stronger technical skills—including more experience with computers—than in the past.

The American Society for Photogrammetry and Remote Sensing has a voluntary certification program for photogrammetrists. To qualify for this professional distinction, individuals must meet work experience standards and pass an oral or written examination.

Job Outlook

Overall employment of surveyors, cartographers, photogrammetrists, and surveying technicians is expected to grow about as fast as the average for all occupations through the year 2010. The widespread availability and use of advanced technologies, such as GPS, GIS, and remote sensing, are increasing both the accuracy and productivity of survey, photogrammetric, and mapping work. However, job openings will continue to result from the need to replace workers who transfer to other occupations or leave the labor force altogether.

Prospects will be best for surveying and mapping technicians, whose numbers are expected to grow slightly faster than the average for all occupations through 2010. The short training period needed to learn to operate the equipment, the current lack of any formal testing or licensing, and the relatively lower wages all make for a healthy demand for these technicians, as well as for a readily available supply.

As technologies become more complex, opportunities will be best for surveyors, cartographers, and photogrammetrists who have at least a bachelor's degree and strong technical skills. Increasing demand for geographic data, as opposed to traditional surveying services, will mean better opportunities for cartographers and photogrammetrists involved in the development and use of geographic and land information systems. New technologies, such as GPS and GIS, also may enhance employment opportunities for surveyors and surveying technicians who have the educational background enabling them to use these systems, but upgraded licensing requirements will continue to limit opportunities for professional advancement for those with less education.

Opportunities for surveyors, cartographers, and photogrammetrists should remain concentrated in engineering, architectural, and

surveying services firms. However, nontraditional areas such as urban planning and natural resource exploration and mapping also should provide areas of employment growth, particularly with regard to producing maps for management of natural emergencies and updating maps with the newly available technology. Continued growth in construction through 2010 should require surveyors to lay out streets, shopping centers, housing developments, factories, office buildings, and recreation areas, while setting aside flood plains, wetlands, wildlife habitats and environmentally sensitive areas for protection. However, employment may fluctuate from year to year along with construction activity, or mapping needs for land and resource management.

Earnings

Median annual earnings of surveyors were \$36,700 in 2000. The middle 50 percent earned between \$26,480 and \$49,030. The lowest 10 percent earned less than \$19,570, and the highest 10 percent earned more than \$62,980.

Median annual earnings of cartographers and photogrammetrists were \$39,410 in 2000. The middle 50 percent earned between \$29,200 and \$51,930. The lowest 10 percent earned less than \$23,560 and the highest 10 percent earned more than \$64,780.

Median hourly earnings of surveying and mapping technicians were \$13.48 in 2000. The middle 50 percent of all surveying technicians earned between \$10.46 and \$17.81 in 2000. The lowest 10 percent earned less than \$8.45, and the highest 10 percent earned more than \$22.40. Median hourly earnings of surveying and mapping technicians employed in engineering and architectural services were \$12.39 in 2000, while those employed by local governments had median hourly earnings of \$15.77.

In 2001, land surveyors in nonsupervisory, supervisory, and managerial positions in the Federal Government earned an average salary of \$57,416; cartographers, \$62,369; geodetic technicians, \$53,143; surveying technicians, \$34,623; and cartographic technicians, \$40,775.

Related Occupations

Surveying is related to the work of civil engineers, architects, and landscape architects, because an accurate survey is the first step in land development and construction projects. Cartography and geodetic surveying are related to the work of environmental scientists and geoscientists, who study the earth's internal composition, surface, and atmosphere. Cartography also is related to the work of geographers and urban and regional planners, who study and decide how the earth's surface is to be used.

Sources of Additional Information

Information about career opportunities, licensure requirements, and the surveying technician certification program is available from:

- National Society of Professional Surveyors, Suite #403, 6 Montgomery Village Ave., Gaithersburg, MD 20879. Internet: <http://www.acsm.net/nsps/index.html>

Information on a career as a geodetic surveyor is available from:

- American Association of Geodetic Surveying (AAGS), Suite #403, 6 Montgomery Village Ave., Gaithersburg, MD 20879. Internet: <http://www.acsm.net>

General information on careers in photogrammetry and remote sensing is available from:

- ASPRS: The Imaging and Geospatial Information Society, 5410 Grosvenor Lane, Suite 210, Bethesda, MD 20814-2160. Internet: <http://www.asprs.org>